US010695779B2

(12) United States Patent
Saine et al.

(10) Patent No.: US 10,695,779 B2
(45) Date of Patent: Jun. 30, 2020

(54) **APPLICATOR HAVING ACTIVE BACKPRESSURE CONTROL DEVICES**

(71) Applicant: **NORDSON CORPORATION**, Westlake, OH (US)

(72) Inventors: **Joel E. Saine**, Dahlonega, GA (US); **Leslie J. Varga**, Cumming, GA (US)

(73) Assignee: **Nordson Corporation**, Westlake, OH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/378,186**

(22) Filed: **Apr. 8, 2019**

(65) **Prior Publication Data**

US 2019/0232309 A1 Aug. 1, 2019

Related U.S. Application Data

(63) Continuation-in-part of application No. 15/698,036, filed on Sep. 7, 2017, now Pat. No. 10,272,464.

(Continued)

(51) **Int. Cl.**

B05B 9/04	(2006.01)
F04B 23/04	(2006.01)
B05C 5/02	(2006.01)
F04B 13/00	(2006.01)
B05C 11/10	(2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***B05B 9/0406*** (2013.01); ***B01F 5/108*** (2013.01); ***B05C 5/001*** (2013.01); ***B05C 5/0279*** (2013.01); ***B05C 11/1013*** (2013.01); ***F04B 13/00*** (2013.01); ***F04B 23/04*** (2013.01); ***F04B 49/20*** (2013.01); *B01F 5/14* (2013.01); *B05C 11/1026* (2013.01); *B05C 11/1042* (2013.01);

(Continued)

(58) **Field of Classification Search**

USPC 156/578

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,228,594 A 7/1993 Aslin
5,236,641 A 8/1993 Allen et al.

(Continued)

FOREIGN PATENT DOCUMENTS

DE 4121792 A1 1/1993
DE 202004001480 U1 4/2004

(Continued)

OTHER PUBLICATIONS

ISA/220—Notification of Transmittal or Search Report and Written Opinion of the ISA, or the Declaration dated Jan 8, 2018 for WO Application No. PCT/US17/050380.

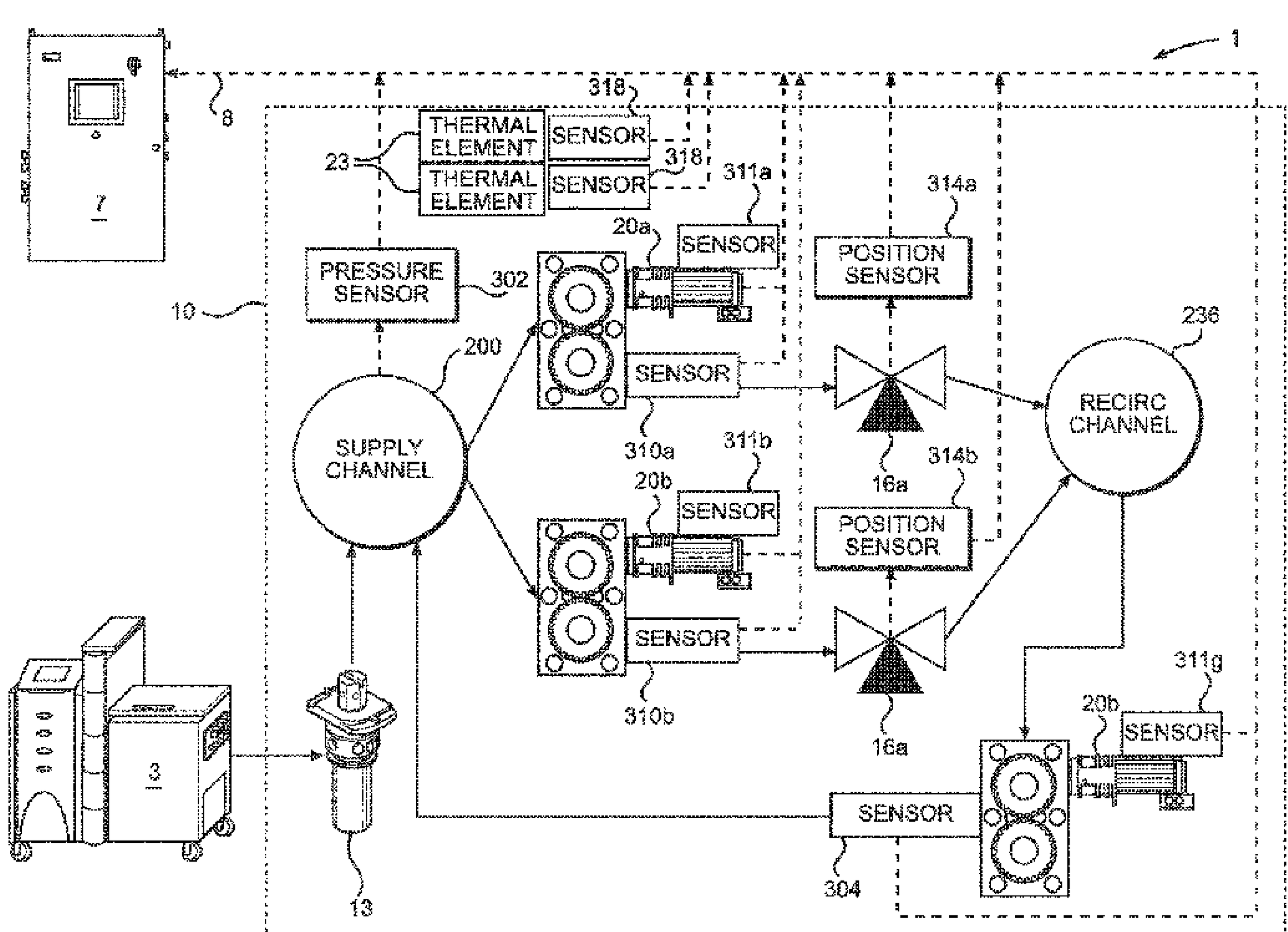
(Continued)

Primary Examiner — Sing P Chan
(74) *Attorney, Agent, or Firm* — Baker & Hostetler LLP

(57) **ABSTRACT**

The present disclosure describes a method and system for controlling dispensing of adhesive from an applicator. The method includes pumping adhesive from a plurality of pump assemblies to a plurality of dispensing modules and measuring current draw from each of the plurality of pump assemblies. The method also includes determining an adjustment to an operating speed of each of the plurality of pump assemblies individually based on their respective current draws and adjusting the operating speed of each of the plurality of pump assemblies individually.

25 Claims, 17 Drawing Sheets



Related U.S. Application Data

(60) Provisional application No. 62/385,238, filed on Sep. 8, 2016.

(51) **Int. Cl.**

F04B 49/20	(2006.01)
B05C 5/00	(2006.01)
B01F 5/10	(2006.01)
B01F 5/14	(2006.01)

(52) **U.S. Cl.**
CPC ... *F04B 2203/0207* (2013.01); *F04B 2205/05* (2013.01); *F04B 2205/09* (2013.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,409,642	A	4/1995	Allen et al.	
5,620,315	A	4/1997	Pfuhler	
5,632,938	A	5/1997	Buehning	
5,727,933	A	3/1998	Laskaris et al.	
5,862,986	A	1/1999	Bolyard et al.	
6,089,413	A	7/2000	Riney et al.	
6,210,141	B1	4/2001	Allen	
6,296,463	B1	10/2001	Allen	
6,422,428	B1	7/2002	Allen et al.	
6,517,891	B1	2/2003	Estelle et al.	
6,607,104	B2	8/2003	McGuffey	
6,688,498	B1	2/2004	McGuffey	
7,699,243	B2	4/2010	Starke	
7,908,997	B2	3/2011	Lessley et al.	
8,445,061	B2	5/2013	McGuffey	
8,561,656	B2	10/2013	Eginton et al.	
9,126,222	B2	9/2015	McGuffey	
9,415,415	B1	8/2016	Jones	
9,427,766	B2	8/2016	Varga	
9,573,159	B2	2/2017	McGuffey	
9,889,599	B2	2/2018	Ayers	
9,925,552	B2	3/2018	Saine	
2001/0024618	A1	9/2001	Winmill	
2002/0102324	A1	8/2002	Groleau	
2002/0139818	A1	10/2002	McGuffey	
2003/0062384	A1	4/2003	McGuffey	
2004/0099752	A1	5/2004	Boger	
2004/0124251	A1	7/2004	Gressett et al.	
2004/0159672	A1	8/2004	Auber et al.	
2005/0230423	A1	10/2005	Riney et al.	
2005/0242108	A1	11/2005	Harris et al.	
2005/0274317	A1	12/2005	De et al.	
2006/0182887	A1	8/2006	Miller	
2008/0135650	A1	6/2008	Starke	
2009/0266844	A1	10/2009	McGuffey	
2012/0048447	A1	3/2012	Burmester et al.	
2013/0108494	A1	5/2013	Varga	
2015/0190837	A1	7/2015	Burmester et al.	
2015/0352588	A1	12/2015	Lessley et al.	
2016/0256889	A1	9/2016	Jones	
2016/0303597	A1	10/2016	McGuffey	
2017/0072624	A1	3/2017	Ayers	
2017/0097019	A1	4/2017	Afshari	
2017/0146035	A1	5/2017	Afshari	
2018/0065137	A1	3/2018	Saine	
2018/0065139	A1	3/2018	Saine	
2018/0065140	A1	3/2018	Saine et al.	
2018/0252213	A1*	9/2018	Afshari	F04C 11/00
2018/0266415	A1*	9/2018	Afshari	F15B 15/18
2018/0291895	A1*	10/2018	Afshari	F04B 9/105
2019/0299237	A1*	10/2019	Scharen	B42C 9/0006

FOREIGN PATENT DOCUMENTS

EP	1442798	A2	8/2004
EP	2289633	A2	3/2011
EP	3064279	A1	9/2016
EP	3064280	A1	9/2016
JP	09-173917	A	7/1997
WO	93/05212	A2	3/1993
WO	99/54044	A1	10/1999
WO	99/54055	A1	10/1999
WO	20071084891	A2	7/2007
WO	20111008390	A1	1/2011
WO	2011/025603	A1	3/2011

OTHER PUBLICATIONS

ISA/220—Notification of Transmittal or Search Report and Written Opinion of the ISA, or the Declaration dated Dec 20, 2017 for WO Application No. PCT/US17/050373.

ISA/220—Notification of Transmittal or Search Report and Written Opinion of the ISA, or the Declaration dated Dec 20, 2017 for WO Application No. PCT/US17/050368.

ISA/206—Invitation to Pay Additional Fees dated Jan 5, 2018 for WO Application No. PCT/US17/50406.

International Patent Application No. PCT/US2017/050406; Int'l Search Report and the Written Opinion; dated Mar. 19, 2018; 19 pages.

English Translation of International Preliminary Report on Patentability Chapter II or English Translation of International Preliminary Report on Patentability Chapter I dated Mar 21, 2019 for WO Application No. PCT/US17/050373.

English Translation of International Preliminary Report on Patentability Chapter II or English Translation of International Preliminary Report on Patentability Chapter I dated Mar 21, 2019 for WO Application No. PCT/US17/050368.

English Translation of International Preliminary Report on Patentability Chapter II or English Translation of International Preliminary Report on Patentability Chapter I dated Dec 13, 2018 for WO Application No. PCT/US17/050417.

(IPEA/409) International Preliminary Report on Patentability Chapter II or (IB/373) International Preliminary Report on Patentability Chapter I dated Mar 21, 2019 for WO Application No. PCT/US17/050509.

(IPEA/409) International Preliminary Report on Patentability Chapter II or (IB/373) International Preliminary Report on Patentability Chapter I dated Mar 21, 2019 for WO Application No. PCT/US17/050406.

(IPEA/409) International Preliminary Report on Patentability Chapter II or (IB/373) International Preliminary Report on Patentability Chapter I dated Mar 21, 2019 for WO Application No. PCT/US17/050380.

(IPEA/409) International Preliminary Report on Patentability Chapter II or (IB/373) International Preliminary Report on Patentability Chapter I dated Mar 21, 2019 for WO Application No. PCT/US17/050373.

(IPEA/409) International Preliminary Report on Patentability Chapter II or (IB/373) International Preliminary Report on Patentability Chapter I mailed on Mar 21, 2019 for WO Application No. PCT/US17/050368.

(IPEA/408) Written opinion under Chapter II dated Aug 3, 2018 for WO Application No. PCT/US17/050417.

* cited by examiner

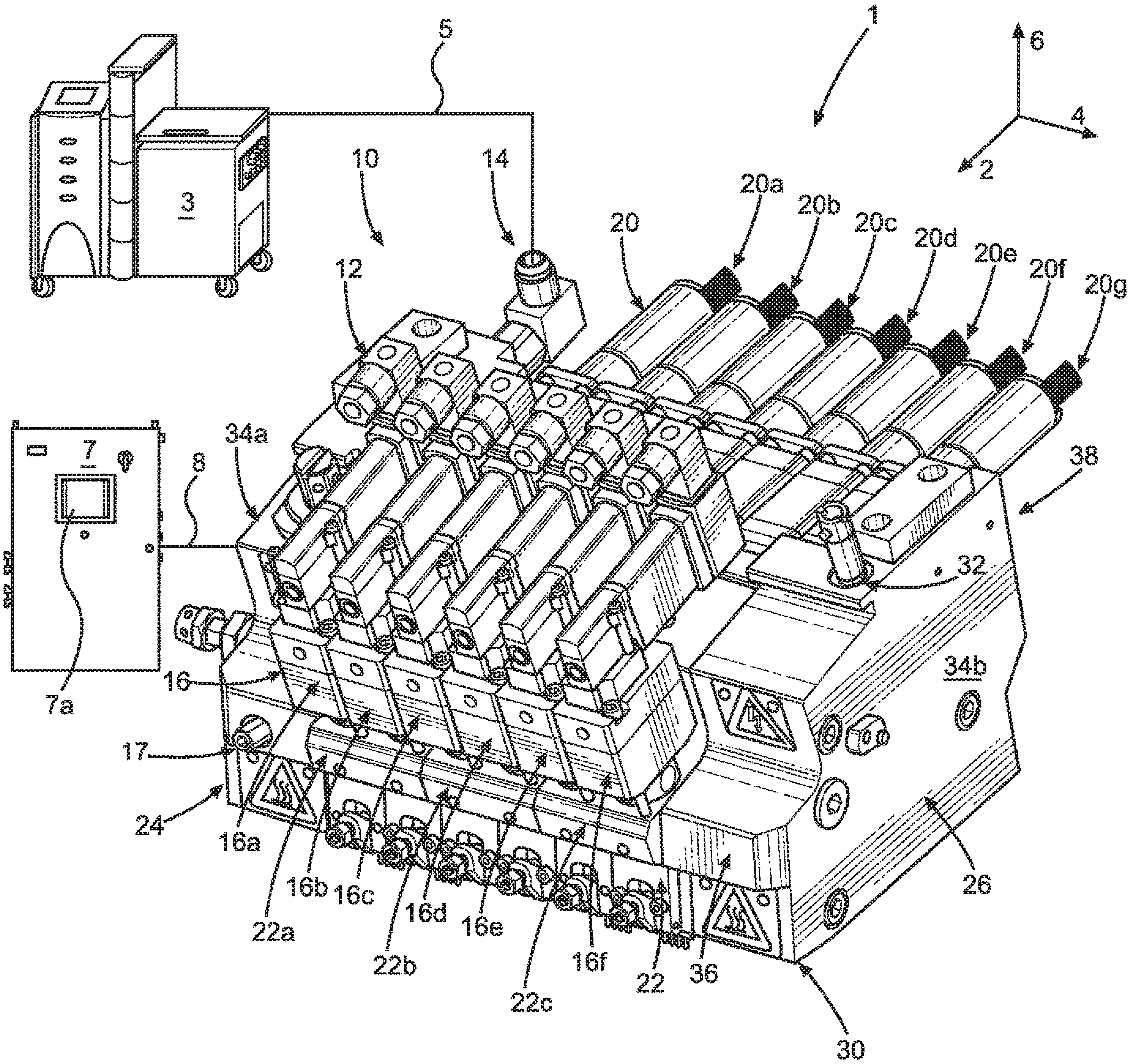

1
6
4
2
5
3
10
14
12
20
20a
20b
20c
20d
20e
20f
20g
7
8
34a
38
7a
32
16
34b
17
24
26
16a
16b
16c
16d
16e
22a
22b
22c
16f
22
36
30

FIG. 1

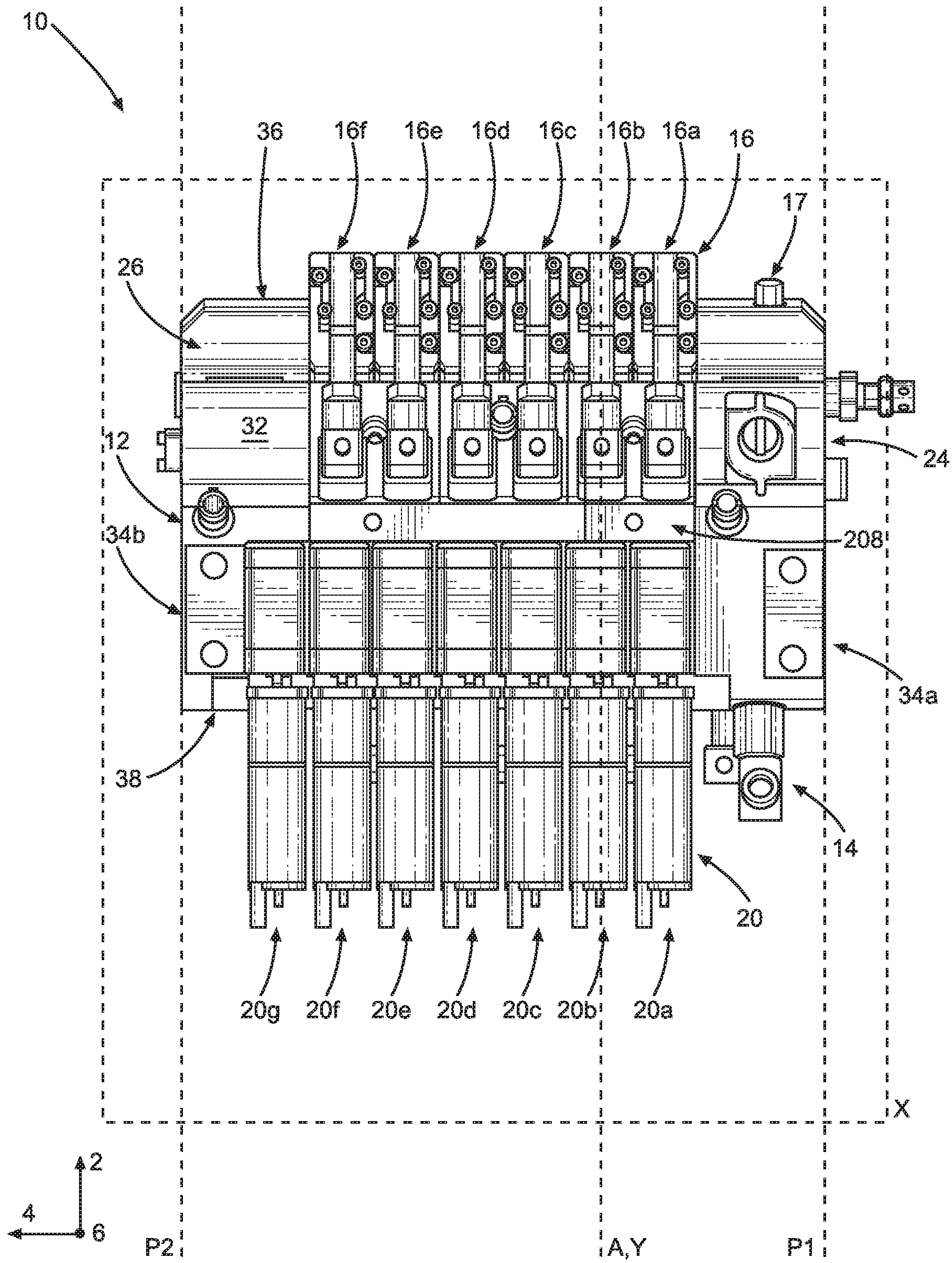

10
36
16f
16e
16d
16c
16b
16a
16
17
26
32
12
24
34b
208
34a
38
14
20
20g
20f
20e
20d
20c
20b
20a
X
2
4
6
P2
A,Y
P1

FIG. 2

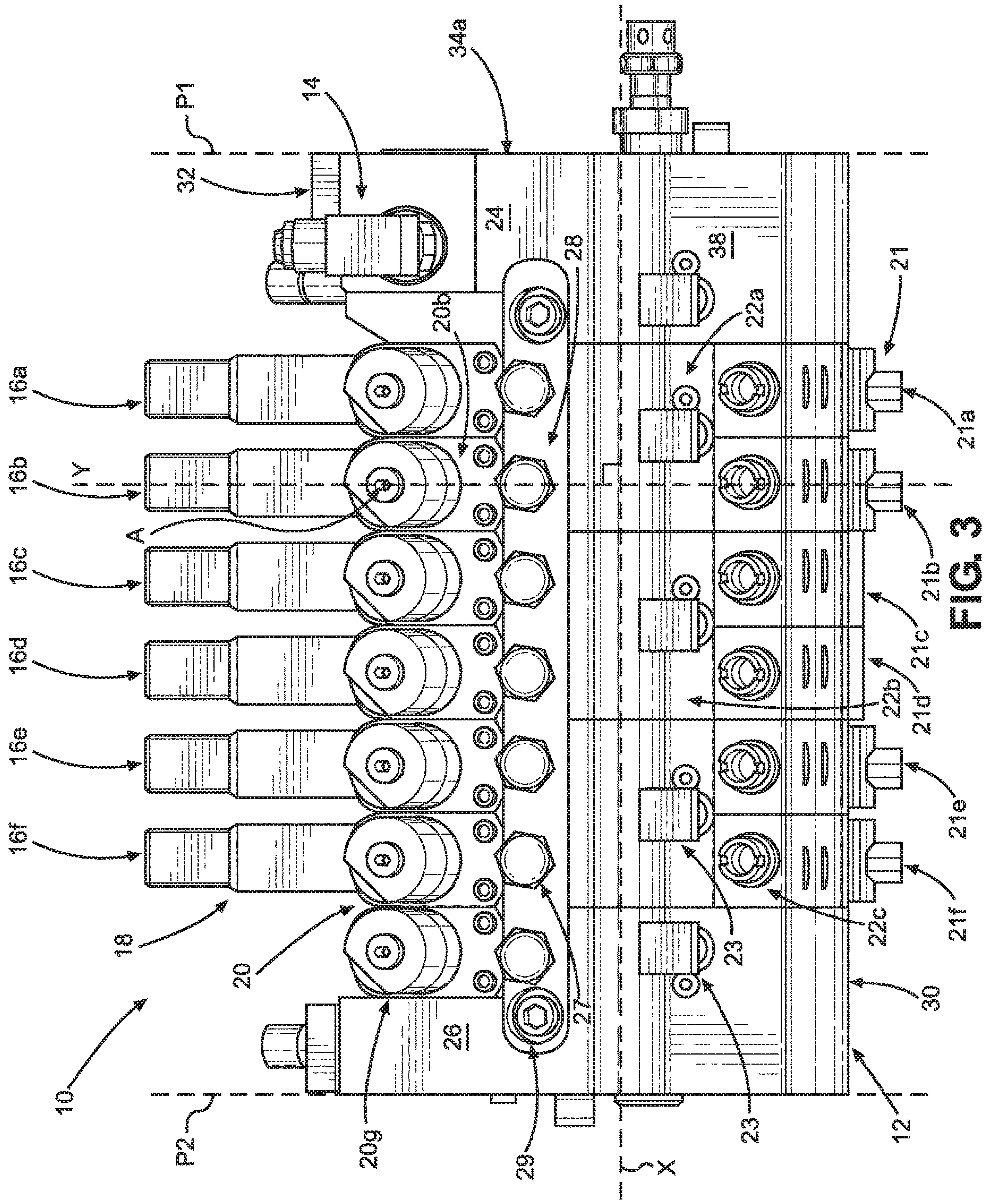

P1
14
34a
32
24
28
38
21
22a
20b
16a
16b
Y
A
21a
16c
21b
16d
21c
22b
21d
16e
21e
16f
18
20
23
22c
21f
30
27
26
10
20g
29
23
12
P2
X

FIG. 3

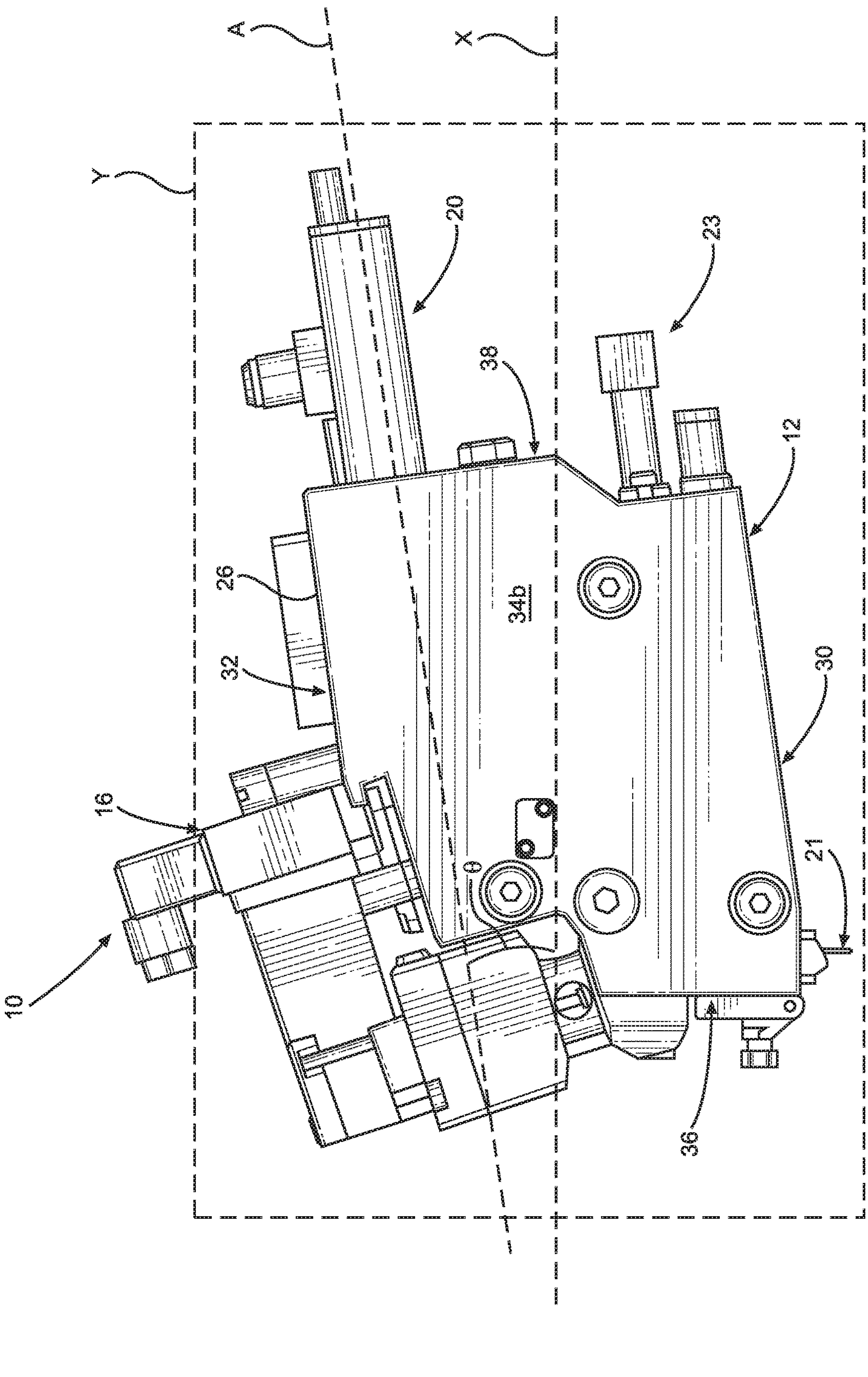


FIG. 4

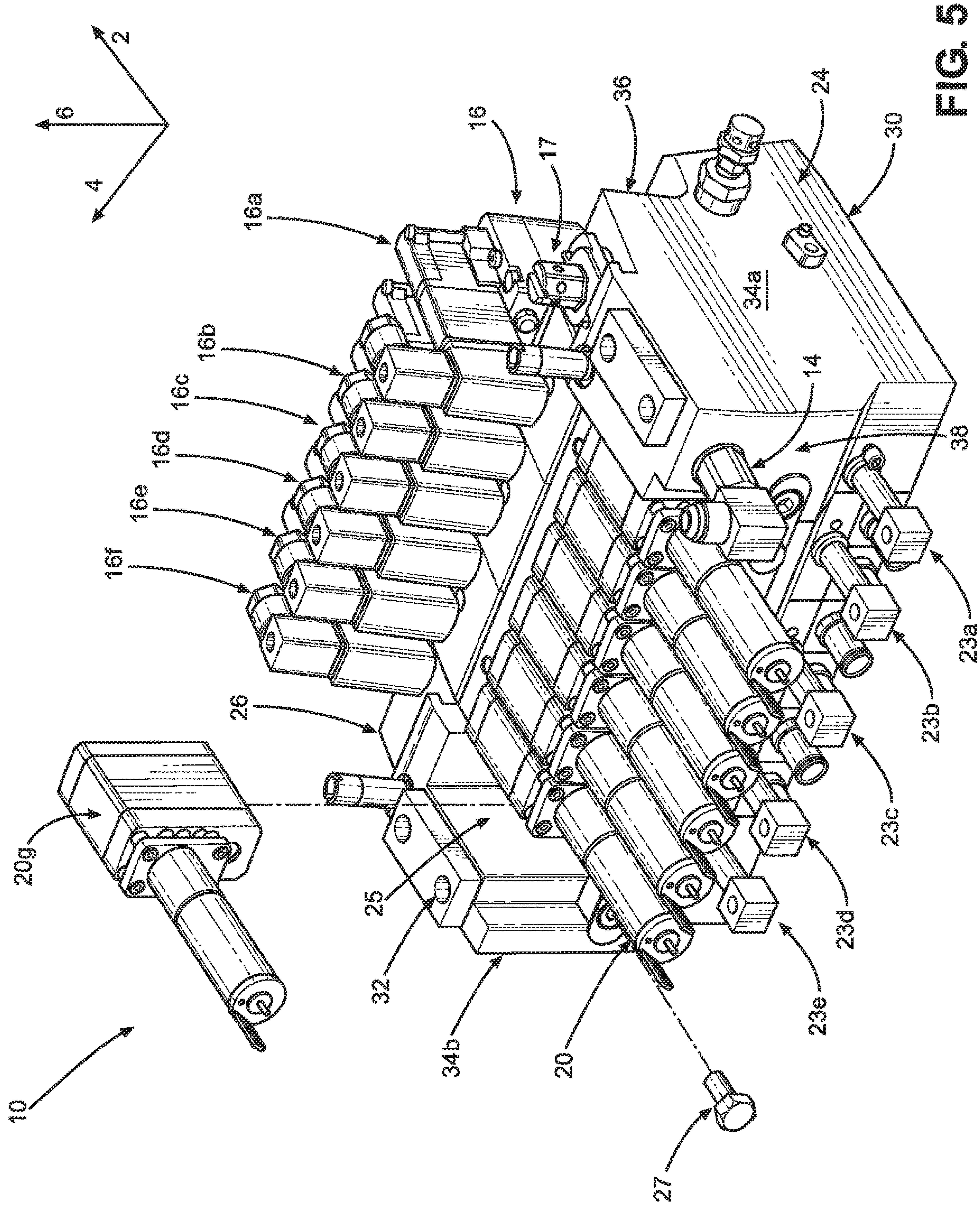

2
6
4
16
16a
17
36
24
30
34a
16b
16c
16d
16e
16f
14
38
23a
23b
23c
23d
23e
26
20g
25
32
34b
20
27
10

FIG. 5

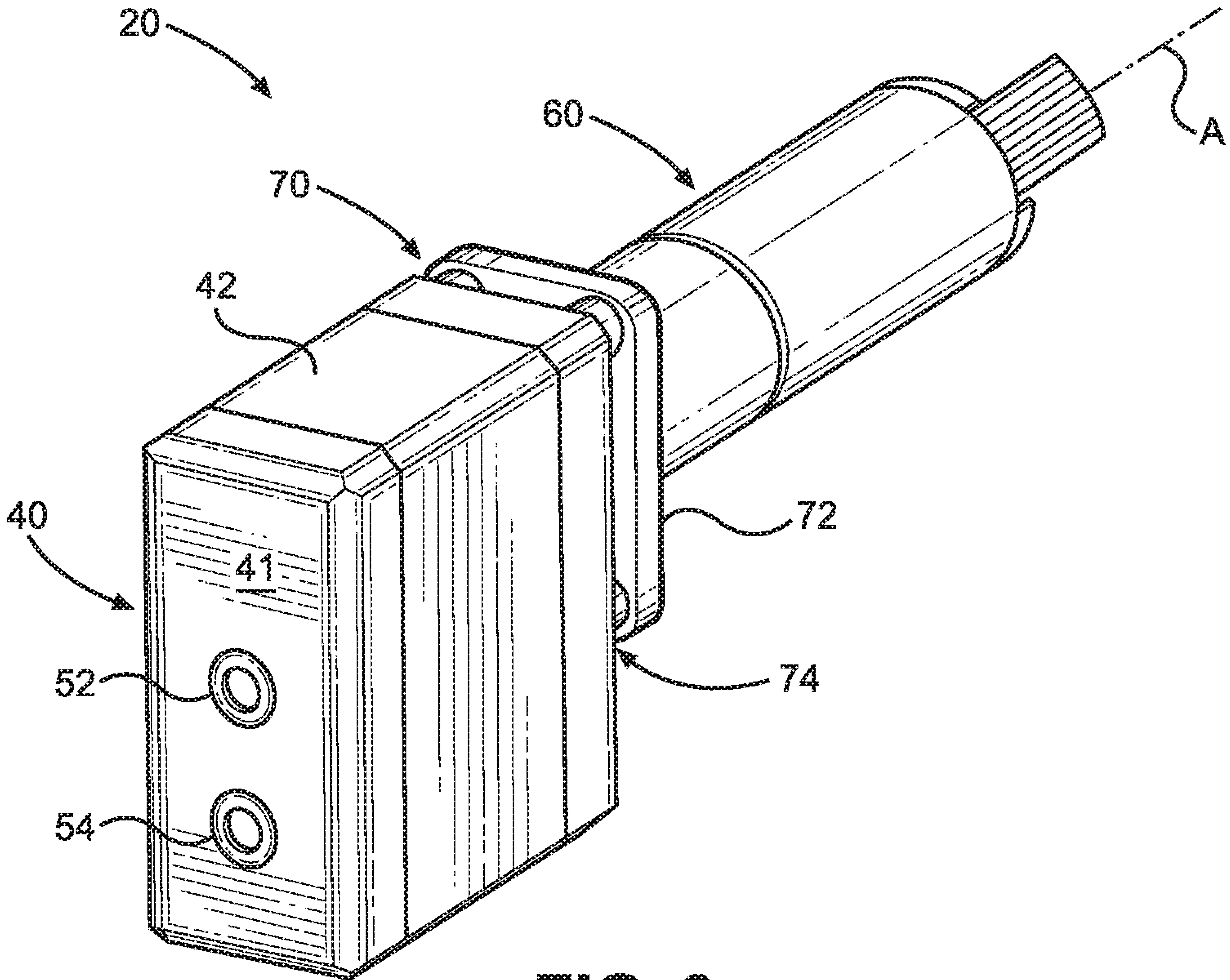


FIG. 6

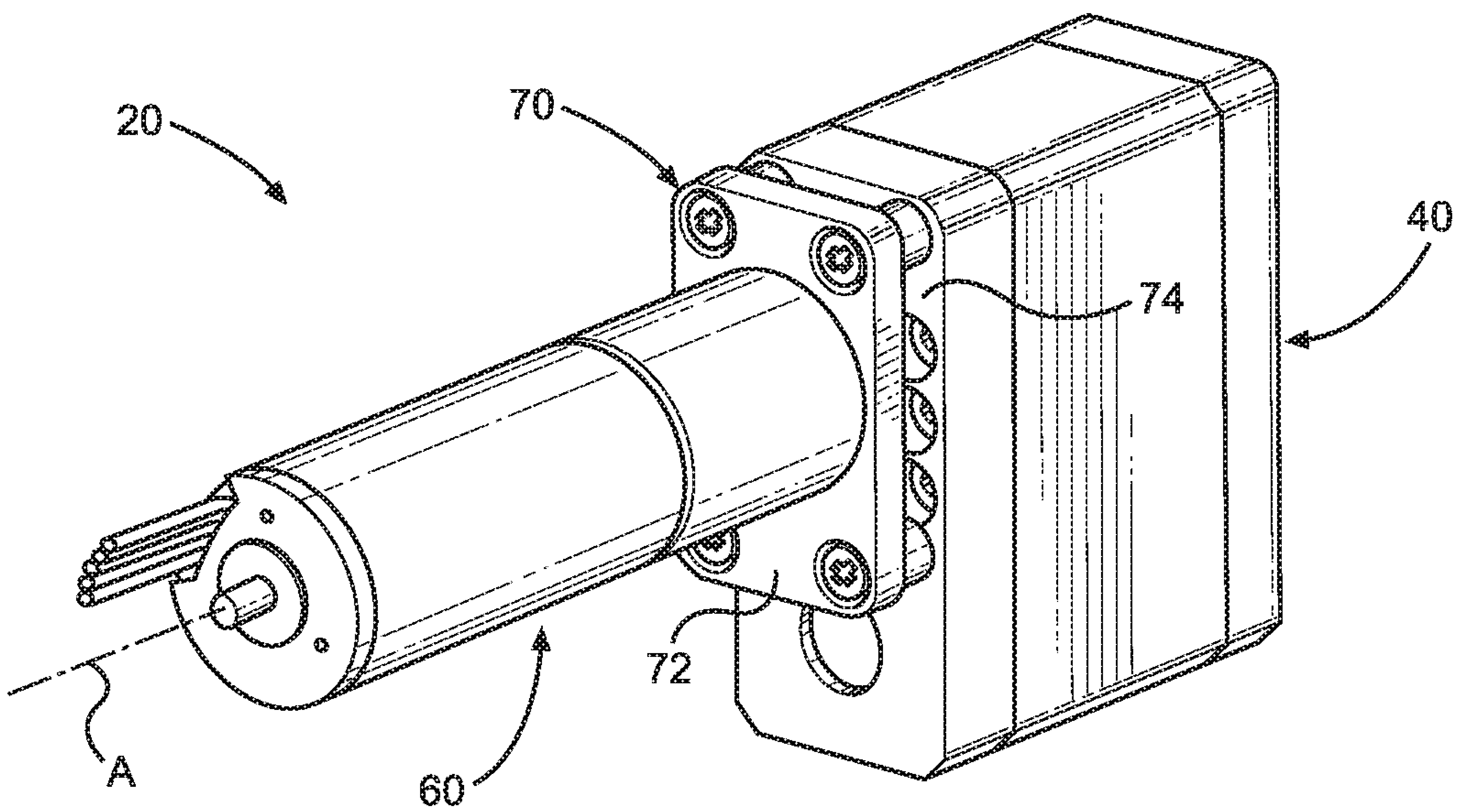


FIG. 7

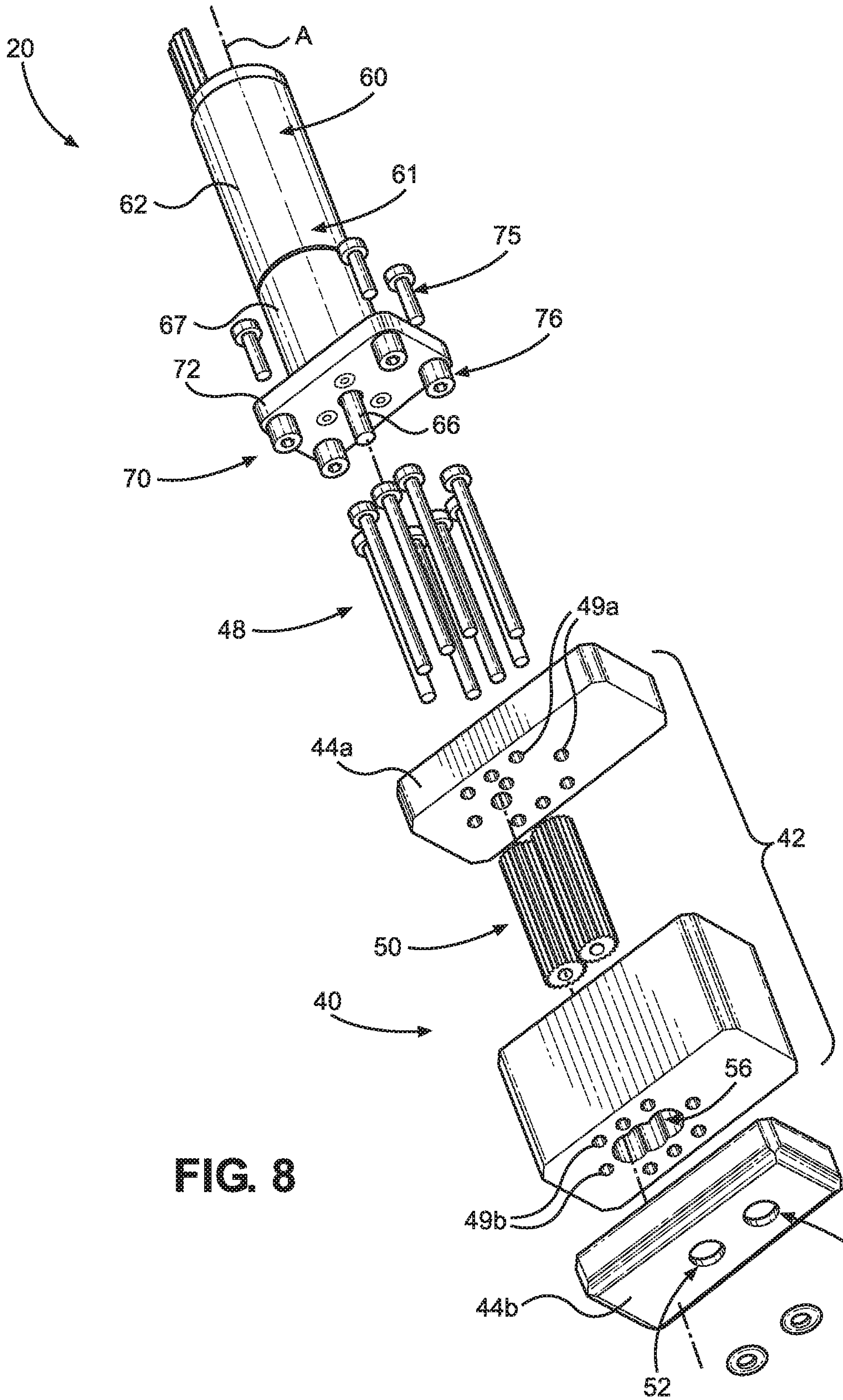


FIG. 8

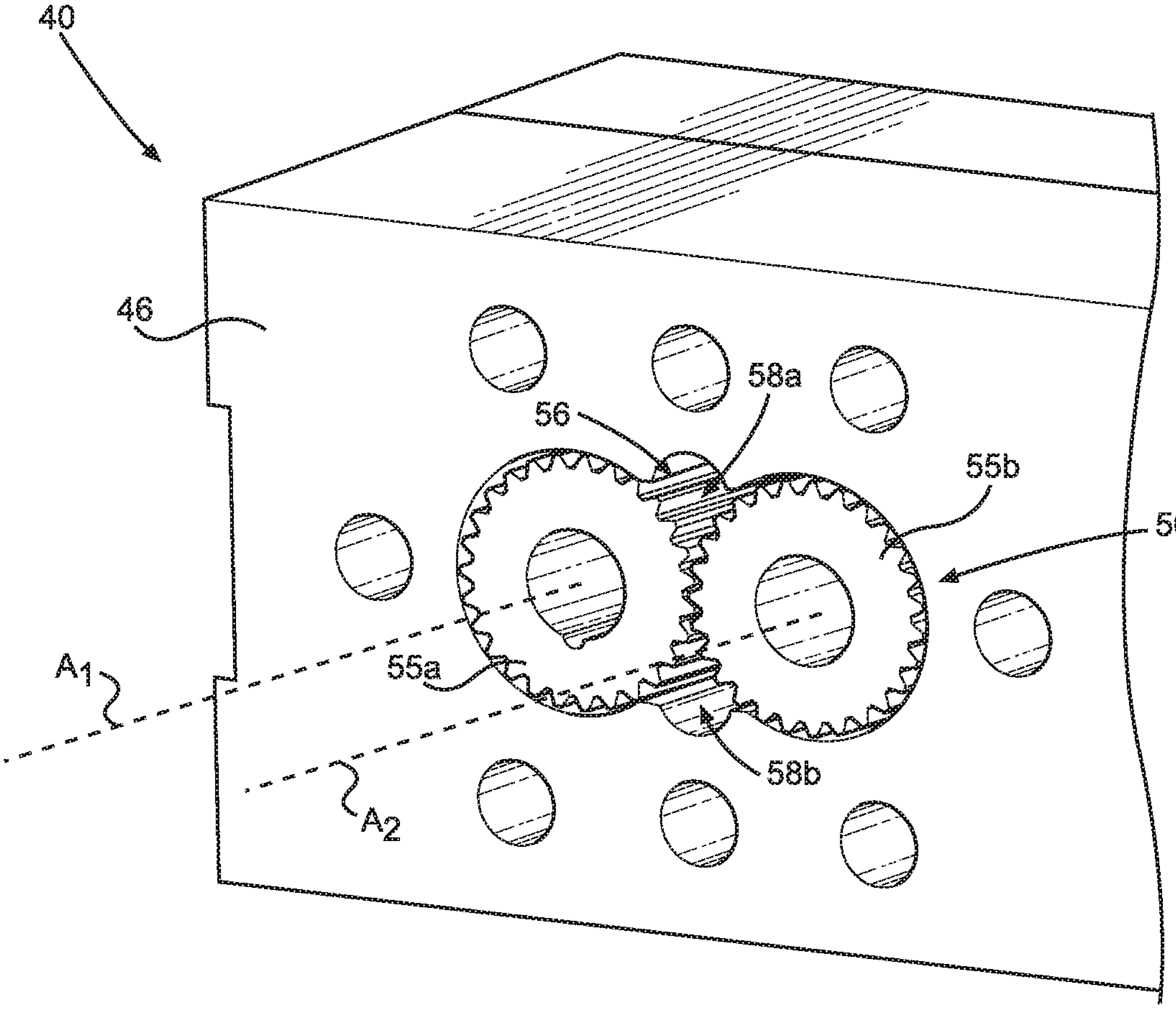


FIG. 9

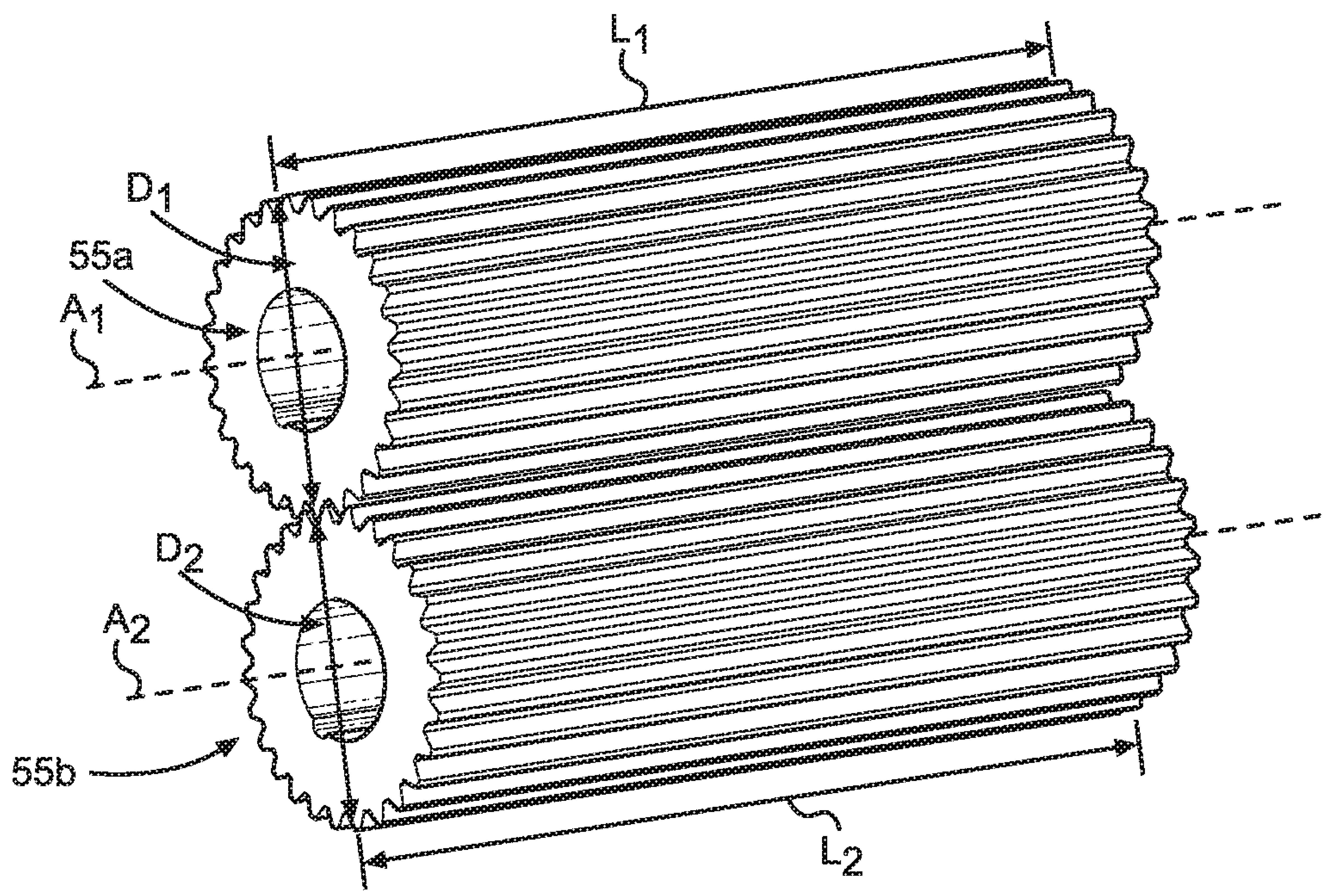


FIG. 10

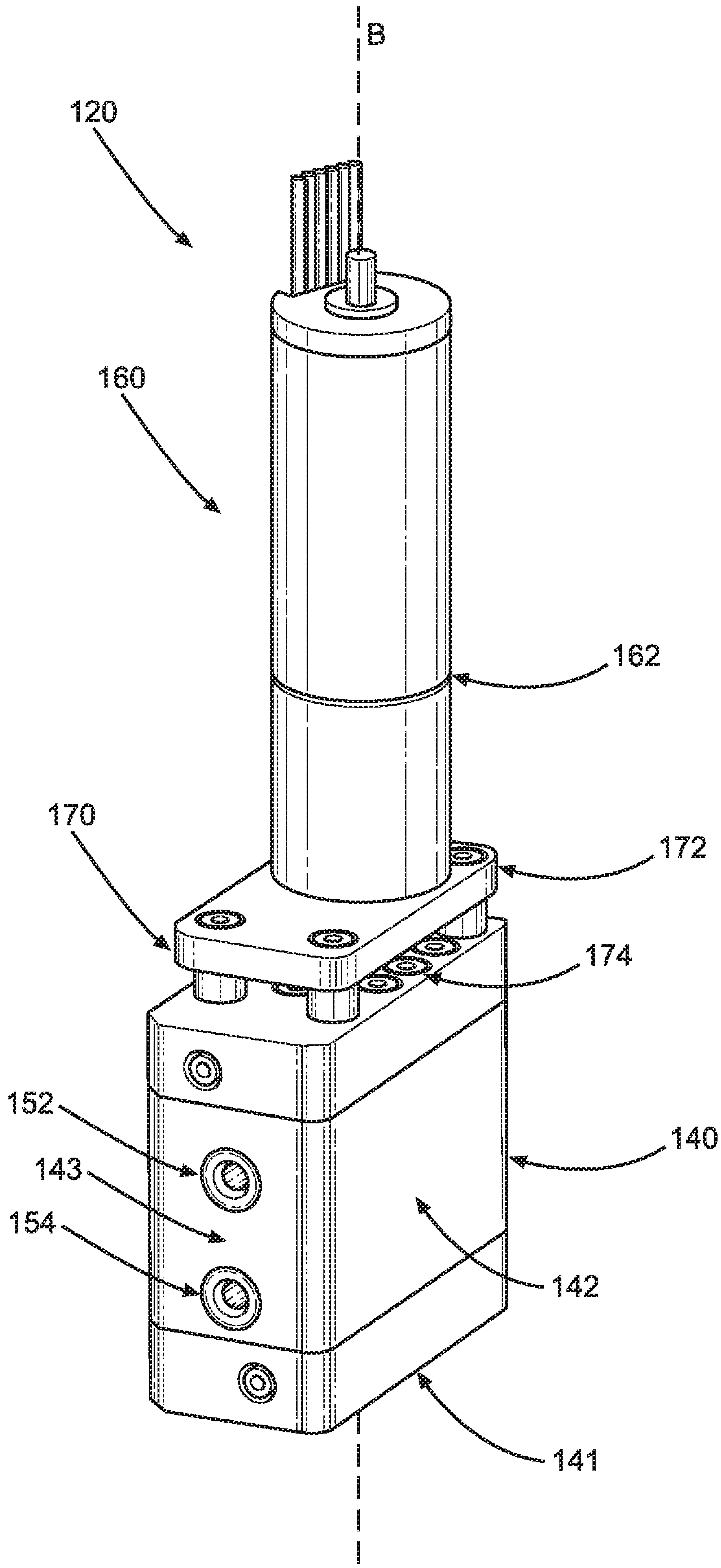


FIG. 11

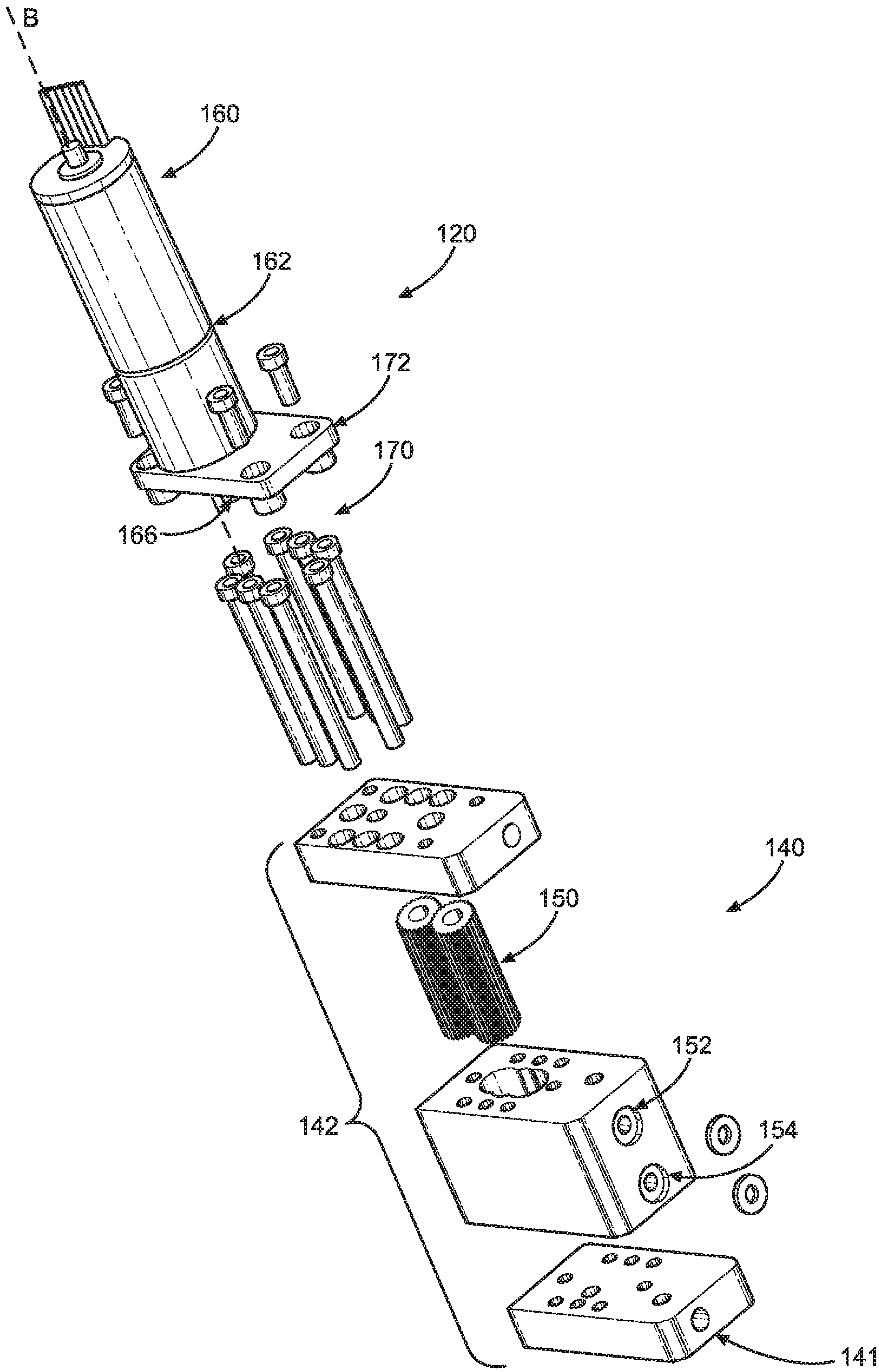


FIG. 12

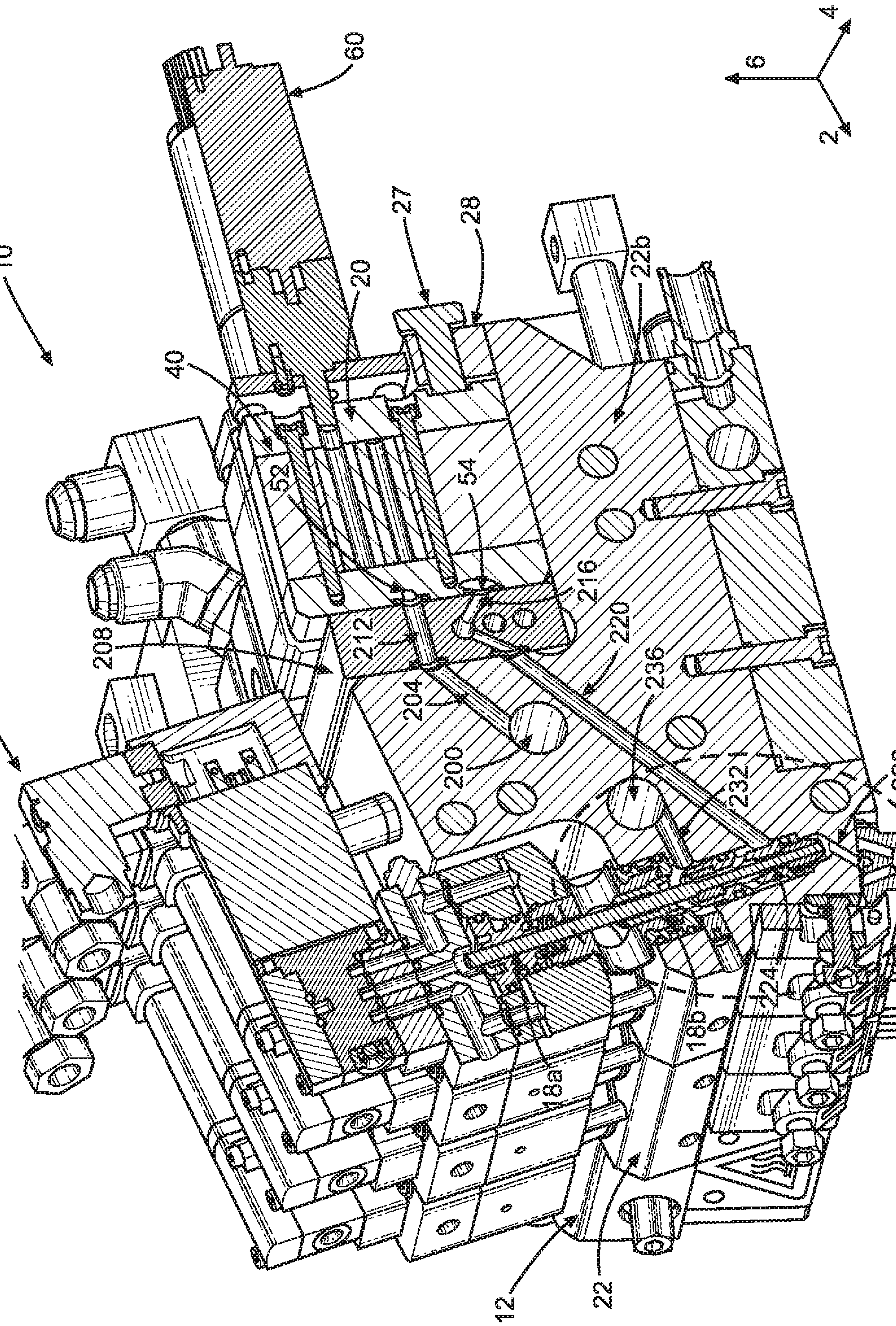

10
16
60
40
52
20
27
28
22b
54
208
212
216
204
220
200
236
232
228
21
224
18b
18a
22
12
6
4
2

FIG. 13

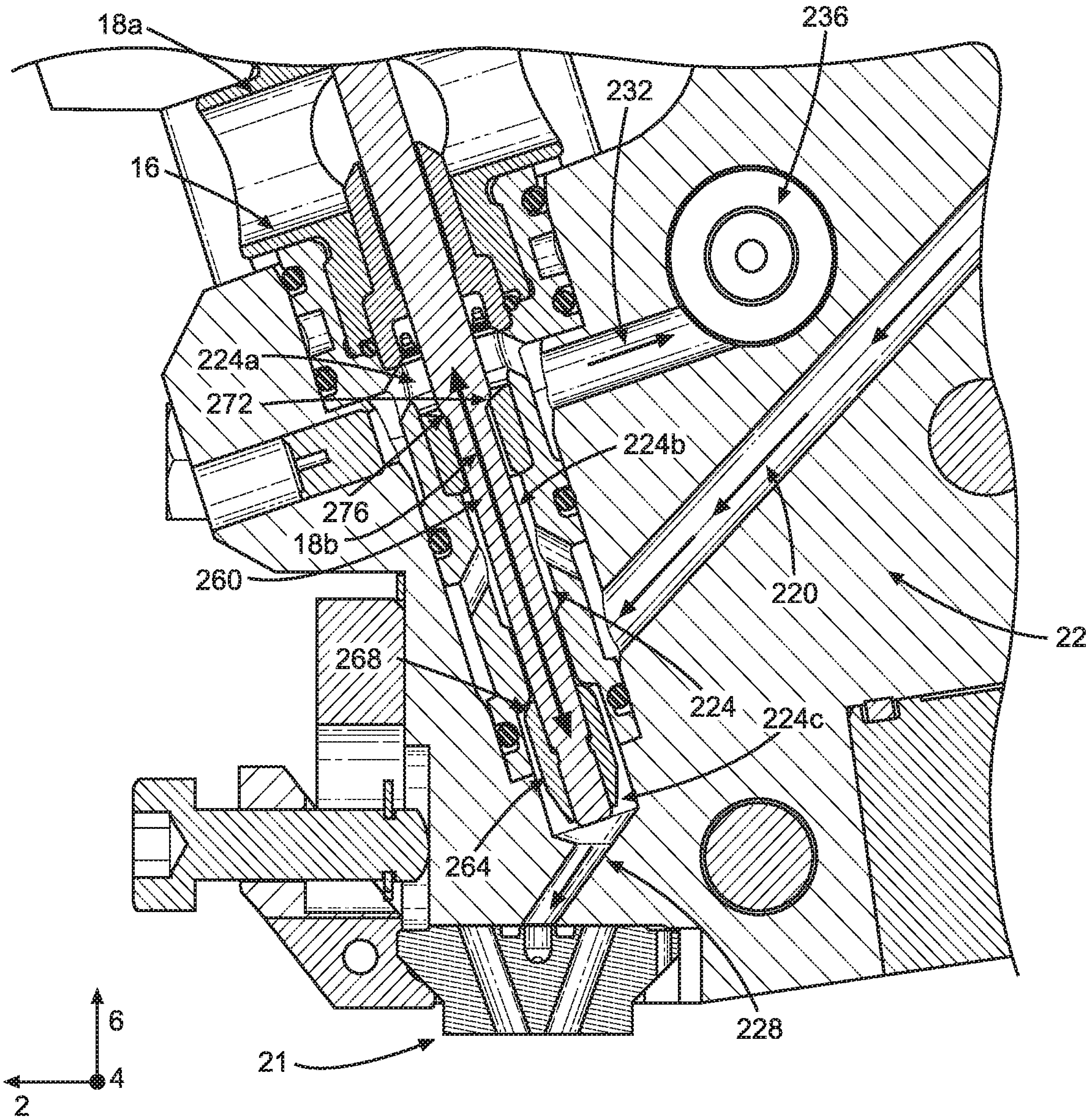

18a
236
232
16
224a
272
224b
276
18b
260
220
22
268
224
224c
264
228
6
4
2
21

FIG. 14

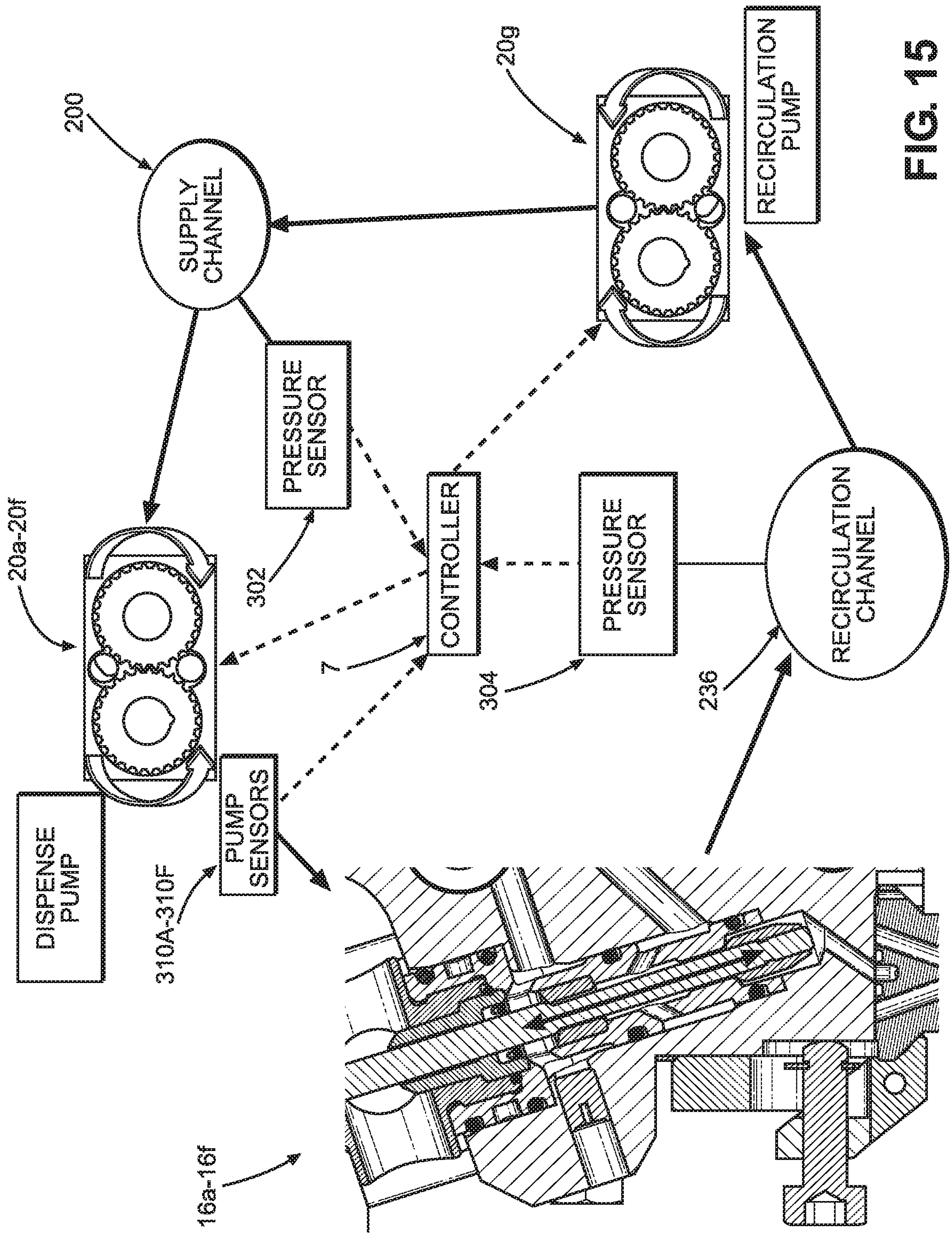

200
SUPPLY CHANNEL
20g
RECIRCULATION PUMP
20a-20f
PRESSURE SENSOR
302
CONTROLLER
7
PRESSURE SENSOR
304
RECIRCULATION CHANNEL
236
DISPENSE PUMP
PUMP SENSORS
310A-310F
16a-16f

FIG. 15

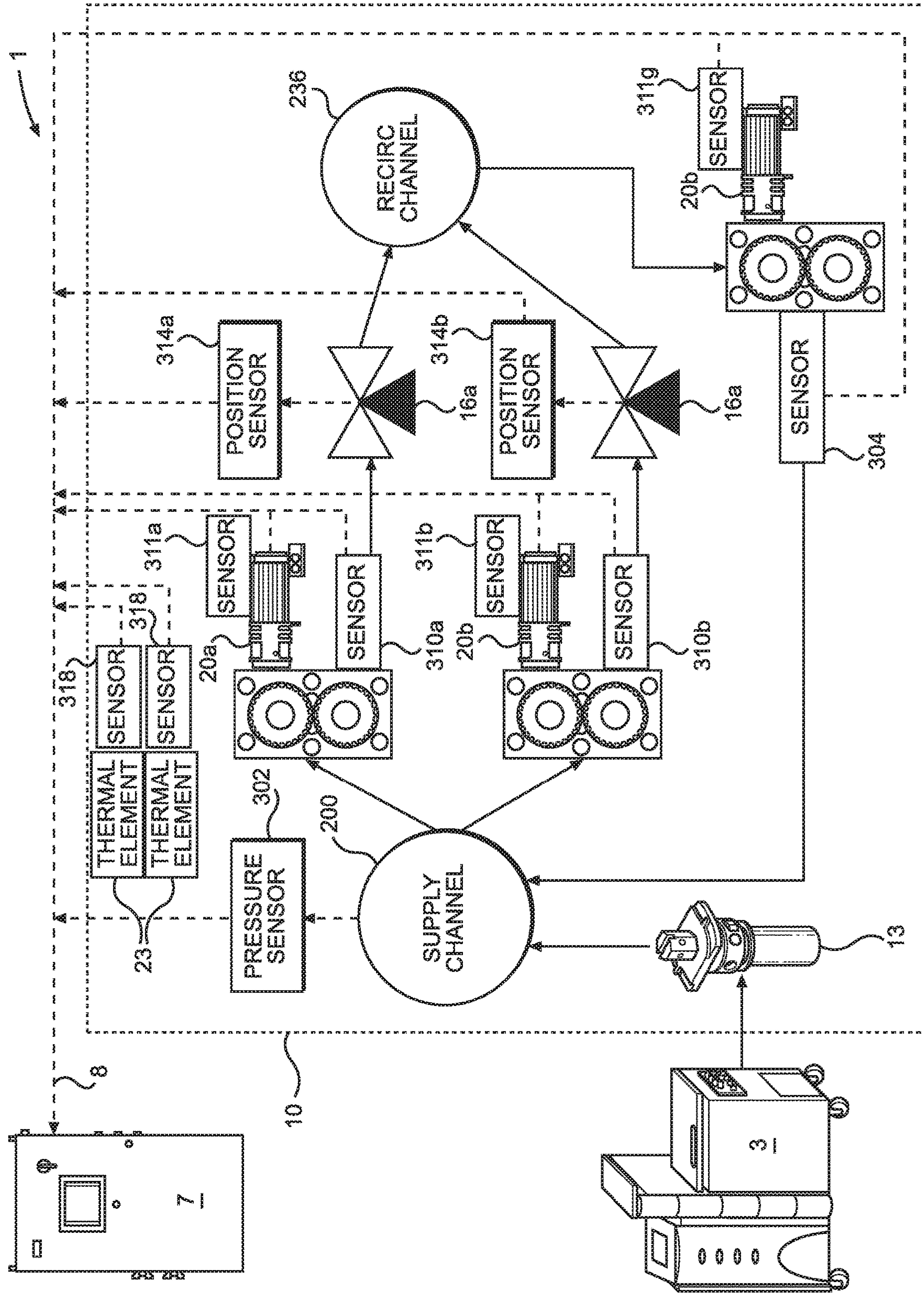

1
236
RECIRC CHANNEL
311g
SENSOR
20b
314a
POSITION SENSOR
16a
314b
POSITION SENSOR
16a
SENSOR
304
311a
SENSOR
318
318
SENSOR
SENSOR
20a
SENSOR
310a
311b
SENSOR
20b
SENSOR
310b
THERMAL ELEMENT
THERMAL ELEMENT
302
200
PRESSURE SENSOR
SUPPLY CHANNEL
23
13
8
10
7
3

FIG. 16

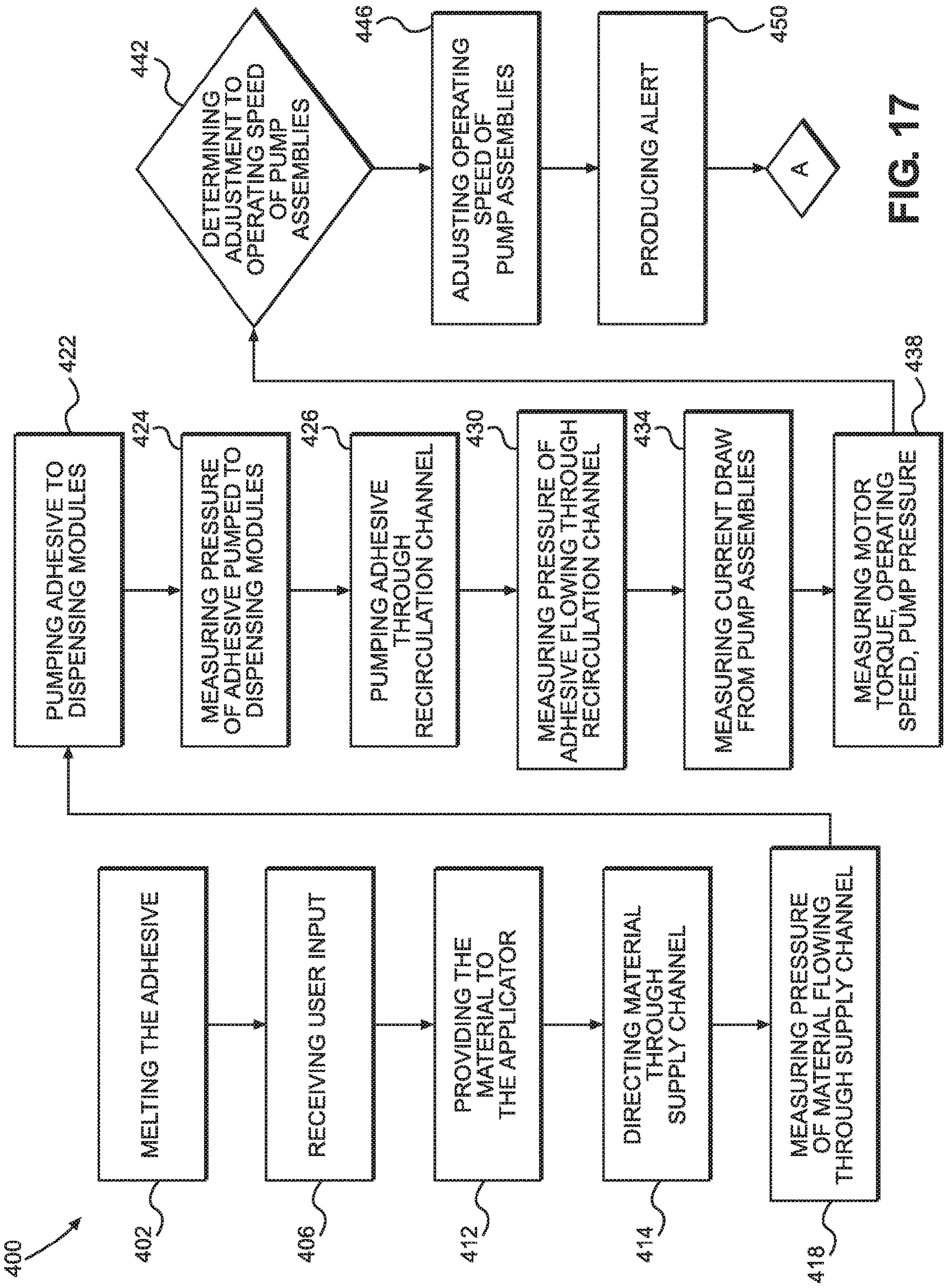

400
MELTING THE ADHESIVE
402
RECEIVING USER INPUT
406
PROVIDING THE MATERIAL TO THE APPLICATOR
412
DIRECTING MATERIAL THROUGH SUPPLY CHANNEL
414
MEASURING PRESSURE OF MATERIAL FLOWING THROUGH SUPPLY CHANNEL
418
PUMPING ADHESIVE TO DISPENSING MODULES
422
MEASURING PRESSURE OF ADHESIVE PUMPED TO DISPENSING MODULES
424
PUMPING ADHESIVE THROUGH RECIRCULATION CHANNEL
426
MEASURING PRESSURE OF ADHESIVE FLOWING THROUGH RECIRCULATION CHANNEL
430
MEASURING CURRENT DRAW FROM PUMP ASSEMBLIES
434
MEASURING MOTOR TORQUE, OPERATING SPEED, PUMP PRESSURE
438
DETERMINING ADJUSTMENT TO OPERATING SPEED OF PUMP ASSEMBLIES
442
ADJUSTING OPERATING SPEED OF PUMP ASSEMBLIES
446
PRODUCING ALERT
450
A

FIG. 17

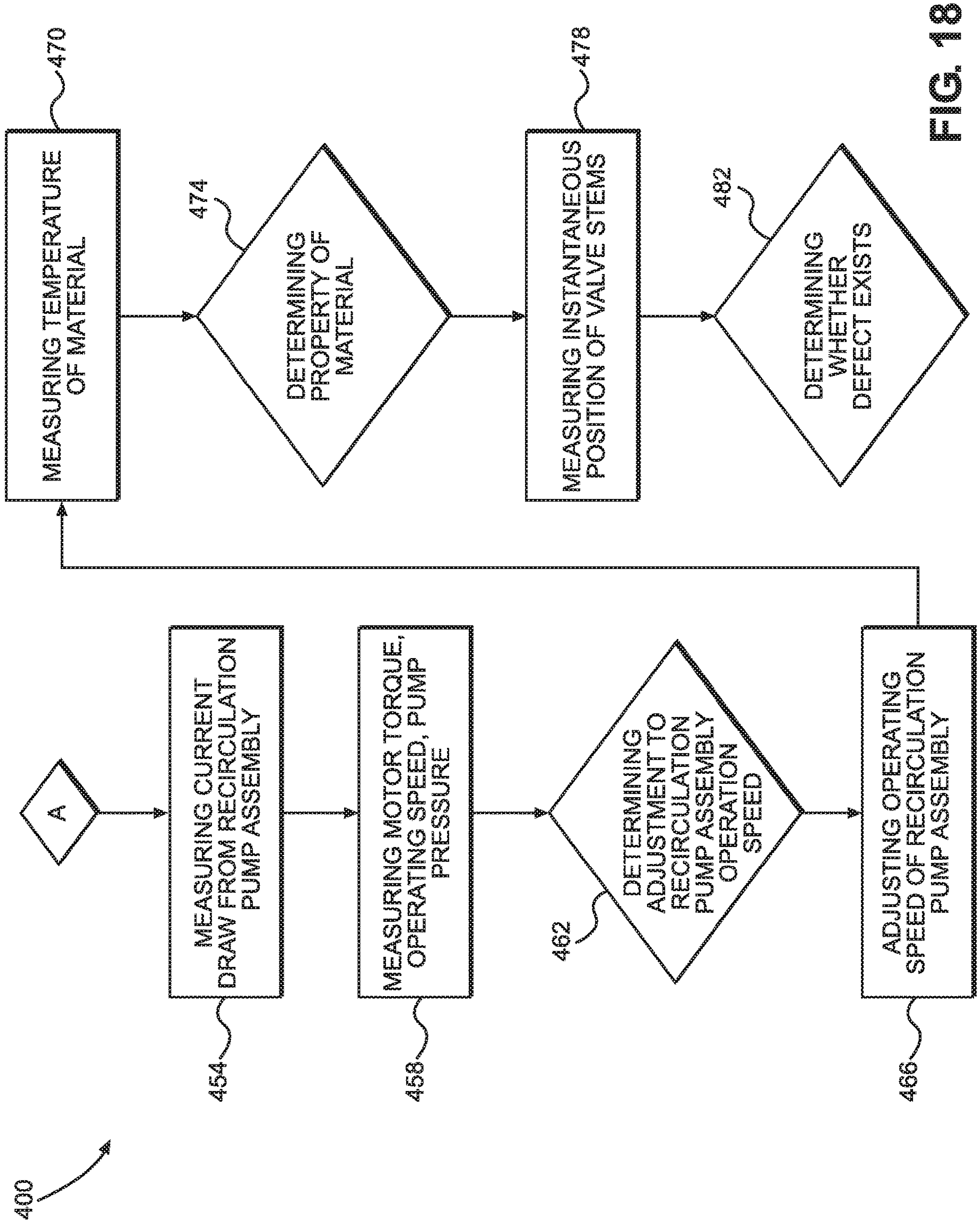

400
A
MEASURING CURRENT DRAW FROM RECIRCULATION PUMP ASSEMBLY
454
MEASURING MOTOR TORQUE, OPERATING SPEED, PUMP PRESSURE
458
DETERMINING ADJUSTMENT TO RECIRCULATION PUMP ASSEMBLY OPERATION SPEED
462
ADJUSTING OPERATING SPEED OF RECIRCULATION PUMP ASSEMBLY
466
MEASURING TEMPERATURE OF MATERIAL
470
DETERMINING PROPERTY OF MATERIAL
474
MEASURING INSTANTANEOUS POSITION OF VALVE STEMS
478
DETERMINING WHETHER DEFECT EXISTS
482

FIG. 18

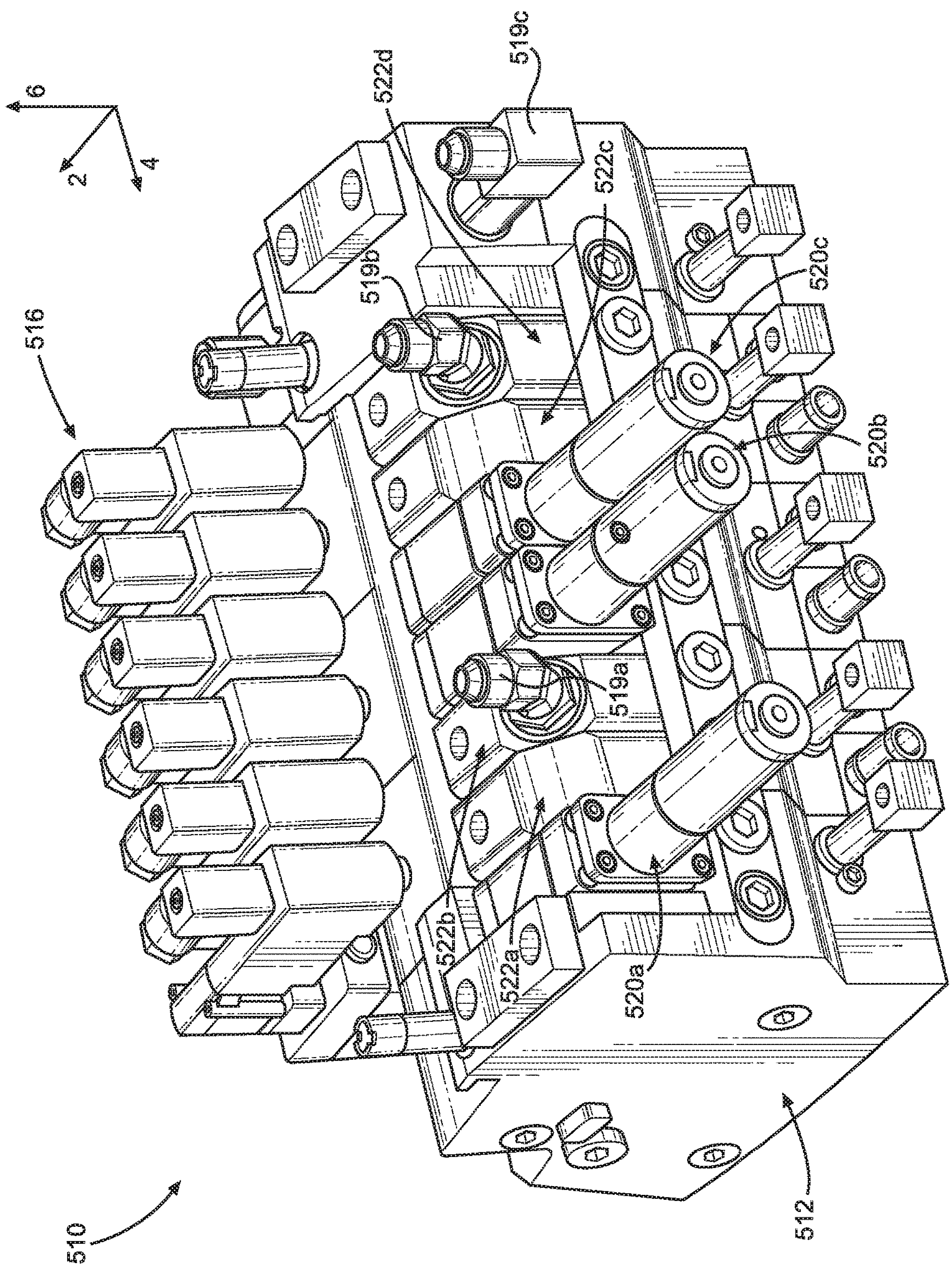

6
2
4
516
522d
519c
519b
522c
520c
520b
519a
522b
522a
520a
510
512

FIG. 19

APPLICATOR HAVING ACTIVE BACKPRESSURE CONTROL DEVICES

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. patent application Ser. No. 15/698,036, filed Sep. 7, 2017, which claims the benefit of U.S. Provisional Patent App. No. 62/385,238, filed Sep. 8, 2016, the disclosures of which are hereby incorporated by reference herein in their entireties.

TECHNICAL FIELD

The present invention relates to an applicator for dispensing an adhesive onto a substrate and components for controlling the pump assemblies of the applicator.

BACKGROUND

Typical applicators for dispensing adhesive may include a plurality of dispensing modules for dispensing the adhesive onto a substrate. Such applicators also typically include a single drive that powers a single pump assembly or a plurality of pump assemblies that pump the material through the applicator. During operation, the applicator may be monitored in order to detect any changes in the flow of adhesive through the applicator, such that an operator of the applicator can respond accordingly. These changes may result from problems occurring within the applicator, such as clogs, worn parts, etc. Additionally, these changes may result from inconsistencies in the physical qualities of the adhesive being provided to the applicator, as it is not uncommon for a supplier to provide a solid material having physical characteristics that are slightly inconsistent within batches or between separate batches. However, given that a single drive may be pumping the adhesive to each of the plurality of dispensing modules, it may take a substantial amount of time after an adhesive flow change occurs within the applicator for the system to detect the change and for an appropriate response to be enacted. This can result in dispensing inconsistencies and inaccuracies, which can create a high amount of wasted products.

Therefore, there is a need for an applicator for dispensing adhesive that monitors the flow of adhesive within the applicator and allows for adjustments to the operation of the pump assemblies of the applicator to be made quickly after a change within the applicator occurs.

SUMMARY

An embodiment of the present disclosure is a dispensing system for dispensing adhesive. The dispensing system includes an applicator comprising a manifold, a plurality of dispensing modules coupled to said manifold, and a plurality of pump assemblies, where each of the plurality of pump assemblies is configured to pump the adhesive to a respective one of the plurality of dispensing modules at a respective operating speed. The dispensing system also includes a controller in signal communication with the applicator, where the controller is configured to a) measure current draw from each of the plurality of pump assemblies, b) determine an adjustment to the operating speed of each of the plurality of pump assemblies individually based on their respective current draws, and c) direct each of the plurality of pump assemblies to individually adjust their operating speed.

Another embodiment of the present disclosure is a method of controlling dispensing of adhesive from an applicator. The method includes pumping adhesive from a plurality of pump assemblies to a plurality of dispensing modules and measuring current draw from each of the plurality of pump assemblies. The method also includes determining an adjustment to an operating speed of each of the plurality of pump assemblies individually based on their respective current draws and adjusting the operating speed of each of the plurality of pump assemblies individually.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing summary, as well as the following detailed description, will be better understood when read in conjunction with the appended drawings. The drawings show illustrative embodiments of the invention. It should be understood, however, that the application is not limited to the precise arrangements and instrumentalities shown.

FIG. **1** is a front perspective view of a dispensing system according to an embodiment of the present invention;

FIG. **2** is a top view of an applicator of the dispensing system shown in FIG. **1**;

FIG. **3** is a rear view of the applicator shown in FIG. **1**;

FIG. **4** is a side view of the applicator shown in FIG. **1**;

FIG. **5** is a rear perspective view of the applicator shown in FIG. **1**, with a recirculation pump assembly removed from the applicator;

FIG. **6** is a bottom perspective view of a pump assembly used in the applicator shown in FIG. **1**;

FIG. **7** is a top perspective view of the pump assembly shown in FIG. **6**;

FIG. **8** is an exploded view of the pump assembly shown in FIG. **6**;

FIG. **9** is a sectional view of the pump assembly shown in FIG. **6**;

FIG. **10** is a perspective view of a gear assembly used in the pump assembly shown in FIGS. **6**-**9**;

FIG. **11** is a perspective view of an alternative pump assembly that can be used in the applicator shown in FIG. **1**;

FIG. **12** is an exploded view of the pump assembly shown in FIG. **11**;

FIG. **13** is a perspective view of the applicator shown in FIG. **1**, in horizontal cross-section.

FIG. **14** is an enhanced view of the encircled region shown in FIG. **13**;

FIG. **15** is a schematic diagram illustrating a method of adhesive recirculation according to an embodiment of the present disclosure;

FIG. **16** is a schematic diagram of the dispensing system shown in FIG. **1** with related sensing components according to an embodiment of the present disclosure;

FIG. **17** is a process flow diagram of a method for controlling the dispensing of adhesive from the applicator the and related sensing components shown in FIG. **16**;

FIG. **18** is a process flow diagram of a continuation of the method for controlling the dispensing of adhesive from the applicator and the related sensing components shown in FIG. **17**; and

FIG. **19** is a rear perspective view of an applicator according to another embodiment of the present invention.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Described herein is a dispensing system **1** including an applicator **10** that includes dispensing modules **16***a*-**16***f*, pump assemblies **20***a*-**20***g*, and a controller **7** for controlling the pump assemblies **20***a*-**20***g*. Certain terminology is used to describe the dispensing system **1** in the following description for convenience only and is not limiting. The words "right," "left," "lower," and "upper" designate directions in the drawings to which reference is made. The words "inner" and "outer" refer to directions toward and away from, respectively, the geometric center of the description to describe the dispensing system **1** and related parts thereof. The words "forward" and "rearward" refer to directions in a longitudinal direction **2** and a direction opposite the longitudinal direction **2** along the dispensing system **1** and related parts thereof. The terminology includes the above-listed words, derivatives thereof, and words of similar import.

Unless otherwise specified herein, the terms "longitudinal," "transverse," and "lateral" are used to describe the orthogonal directional components of various components of the dispensing system **1**, as designated by the longitudinal direction **2**, lateral direction **4**, and transverse direction **6**. It should be appreciated that while the longitudinal and lateral directions **2** and **4** are illustrated as extending along a horizontal plane, and the transverse direction **6** is illustrated as extending along a vertical plane, the planes that encompass the various directions may differ during use.

Embodiments of the present invention include a dispensing system **1** that includes an applicator **10** for dispensing adhesive onto a substrate during product manufacturing. Referring to FIGS. **1**-**5**, the applicator **10** includes a manifold **12**. The applicator **10** has a top surface **32**, a bottom surface **30** opposite the top surface **32** along the transverse direction **6**, a first side surface **34***a*, a second side surface **34***b* opposite the first side surface **34***a* along the lateral direction **4**, a front surface **36**, and a back surface **38** opposite the front surface **36** along the longitudinal direction **2**. The first and second side surfaces **34***a* and **34***b* extend from the front surface **36** to the back surface **38**, as well as from the bottom surface **30** to the top surface **32**. The manifold **12** is defined by a first end plate **24**, a second end plate **26**, and at least one manifold segment **22** disposed between the first and second end plates **24** and **26**. As a result, the first and second end plates **24** and **26** are spaced apart along the lateral direction **4**. The first and second end plates **24** and **26** and the manifold segments **22** may be releasably connected such that manifold segments **22** may be added or taken away from the applicator **10** as operating conditions require. As a result, even though FIGS. **1**-**5** show applicator **10** as including three manifold segments **22***a*-**22***c*, applicator **10** can include more or less manifold segments **22** may as desired. However, in another embodiment, the manifold **12** may be a unitary manifold.

Referring to FIGS. **2**-**4**, the first side surface **34***a* of the manifold **12** lies within a first plane P**1**, while the second side surface **34***b* lies within a second plane P**2**. The second plane P**2** may be parallel to the first plane P**1**. However, the first and second planes P**1** and P**2** may not be parallel if the first and second side surfaces **34***a* and **34***b* are angled with respect to each other. The applicator **10** defines a horizontal plane X, such that the lateral and longitudinal directions **4** and **2** lie within the horizontal plane X. The pump assembly **20** may define a drive shaft axis A that lies within a plane Y. The interrelationship of these planes and axes will be described further below.

The applicator **10** includes an input connector **14**, through which adhesive is pumped into the manifold **12**. The adhesive can be pumped through a hose **5** from a melter **3** to the input connector **14**, where the melter **3** can be configured to receive the adhesive in a solid form and melt the adhesive before providing the adhesive to the applicator **10**. The applicator **10** may include a filter **13** (shown in FIG. **16**) that filters any remaining solid components from the adhesive after it enters the applicator **10**. The manifold **12** may further include a pressure release valve **17** that allows a user to attenuate pressure created by adhesive within the manifold, and a dispensing module **16** for applying the adhesive to a substrate. When the pressure release valve **17** is opened, adhesive may drain from the manifold through a drain (not shown). The applicator **10** also includes a pump assembly **20** removably mounted to the manifold **12**. The pump assembly **20** pumps adhesive flowing from an interior channel of the manifold **12** to the dispensing module **16**, which then dispenses adhesive out of the applicator through a nozzle **21**. The applicator **10** may include thermal elements **23** that are configured to elevate the temperature of the manifold **12**, which, in turn, elevates the temperature of the pump **40** in each pump assembly **20**. Though FIGS. **1**-**5** depict the applicator **10** as including five thermal elements **23***a*-**23***e*, any number of thermal elements **23** can be included as required.

In various embodiments, the applicator **10** includes multiple sets of pump assemblies **20**, dispensing modules **16**, and nozzles **21**. As illustrated in FIGS. **1**-**5**, for example, the applicator **10** is depicted as including seven pump assemblies **20***a*, **20***b*, **20***c*, **20***d*, **20***e*, **20***f*, and **20***g*. Although FIGS. **1**-**5** illustrate seven pump assemblies **20***a*-**20***g*, the applicator **10** can include any number of pump assemblies **20** as desired. For example, the applicator **10** can include two pump assemblies, three pump assemblies, or more than three pump assemblies. The pump assemblies **20***a*-**20***g* may be arranged in a side-by-side configuration to increase the processing width of the applicator **10**. For clarity, a single pump assembly **20** is described below. However, reference number **20** can be used interchangeably with reference numbers **20***a*-**20***g*. Though the pump assemblies **20***a*-**20***g* are depicted as being similarly sized, each of the individual pump assemblies **20** included in the applicator **10** can be individually sized as desired to suit a particular purpose. For example, the recirculation pump assembly **20***g*, which will be described further below, may be larger than the other pump assemblies **20***a*-**20***f*.

Additionally, the applicator **10** is depicted as including six dispensing modules **16***a*, **16***b*, **16***c*, **16***d*, **16***e*, and **16***f*. Although FIGS. **1**-**3** illustrate six dispensing modules **16***a*-**16***f*, the applicator can include any number of dispensing modules **16** as desired. For example, the applicator **10** can include one dispensing module, two dispensing modules, or more than two dispensing modules. Similarly, a single dispensing module **16** is described below. However, the reference number **16** can be used interchangeably with reference numbers **16***a*-**16***f* The applicator **10** is also depicted as including six nozzles **21***a*, **21***b*, **21***c*, **21***d*, **21***e*, and **21***f*. Each of nozzles **21***a*-**21***f* may receive an adhesive feed from a corresponding dispensing module **16**, or a combination of several of the dispensing modules **16***a*-**16***f*. The configuration of the nozzles **21***a*-**21***f* can be changed by a user as operation conditions require, which can include adding additional nozzles **21** or removing any of the nozzles **21***a*-**21***f* that are already coupled to the applicator **10**. Additionally, the nozzles **21***a*-**21***f* can be differently types chosen to suit particular dispensing applications. For example, as shown in FIG. **3**, nozzles **21***a*, **21***b*, **21***e*, and **21***f* can be one type of nozzle, while nozzles **21***c* and **21***d* can be a different type of nozzle.

Continuing with FIGS. **1**-**5**, each of pump assemblies **20***a*-**20***f* may be associated with a corresponding one of the dispensing modules **16***a*-**16***f*. In operation, each of pump assemblies **20***a*-**20***f* may pump fluid that is supplied by the manifold **12** to the corresponding one of the dispensing modules **16***a*-**16***f*, such that the dispensing modules **16***a*-**16***f* apply the adhesive to a given substrate through nozzles **21***a*-**21***d*. However, each dispensing module **16** may not correspond to a single pump assembly **20**, such that multiple pump assemblies **20** pump adhesive to a single dispensing module **16**. Additionally, each of the pump assemblies **20** and each of the dispensing modules **16** may be coupled to and associated with a respective manifold segment **22**. However, two or more pump assemblies **20** and/or two or more dispensing modules **16** may be coupled to a single manifold segment **22**.

The pump assembly **20***g*, however, is not associated with a particular dispensing module **16**, but is designated as the recirculation pump assembly. The function of the recirculation pump assembly **20***g* may include pumping the adhesive through a recirculation channel **236**, as will be described below. As such, the inlet **52** of the pump assembly **20***g* is in fluid communication with the recirculation channel **236**, and the outlet of the pump assembly **20***g* is in fluid communication with the supply channel **200**. Though the pump assembly **20***g* is shown as the pump assembly **20** positioned closest to the second side surface **34***b*, the recirculation pump assembly **20***g* may be positioned anywhere along the series of pump assemblies **20***a*-**20***g*. For example, the recirculation pump assembly **20***g* may be positioned as the pump assembly closest to the first side surface **34***a*, or at a location in the middle of the pump assemblies **20***a*-**20***g*. When the pump assembly **20***g* is positioned as the closest pump to the first or second side surface **34***a* or **34***b* of the applicator **10**, the particular one of the first or second end plates **24** or **26** that the pump assembly **20***g* abuts may be configured to receive a portion of the pump assembly **20***g*. For example, as shown in FIG. **5**, the second end plate **26** includes a recess **25** that is sized to receive a housing assembly **42** of the pump assembly **20***g*. When the pump assembly **20***g* is disposed in the recess **25**, the pump assembly **20***g* may be substantially in line with the other pump assemblies **20***a*-**20***f* along the longitudinal and transverse directions **2** and **6**.

Additionally, though in this embodiment pump assembly **20***g* is configured to be the sole recirculation pump assembly for the applicator **10**, it is contemplated that in other embodiments the applicator **10** can include multiple recirculation pump assemblies (not shown), each of which can be similarly configured as pump assembly **20***g*. For example, each dispensing module **16** can correspond to a unique recirculation pump assembly. Alternatively, the applicator **10** can include multiple recirculation pump assemblies that collectively pump adhesive through a single recirculation channel. In another embodiment with multiple recirculation pump assemblies, each recirculation pump assembly can pump adhesive through separate respective recirculation channels. Further, in other embodiments the applicator **10** can include a pump assembly that includes the functionality of both pumping adhesive to a dispensing module **16**, as well as pumping adhesive through the recirculation channel. Such a pump assembly may be configured as a single dual-gear stack pump, where one gear stack functions to pump adhesive to a dispensing module **16**, while the other functions to pump adhesive through the recirculation channel. Each gear stack can contain one driving gear and one driven gear, and each gear stack can be contained within a common pump body. Alternatively, each gear stack can be contained within separate respective pump bodies. Further, each gear stack can be driven by a common motor, or alternatively be independently driven by separate respective motors.

Referring to FIGS. **6**-**10**, each pump assembly **20***a*-**20***g* includes a pump **40** and a dedicated drive motor unit **60** that powers the pump **40**. Because each pump **40** has a dedicated drive motor unit **60**, each pump assembly **20** can be independently controlled by the operator and/or a control system (not shown). The pump assembly **20** also includes a thermal isolation region **70** positioned between the pump **40** and the drive motor unit **60**. Thermal elements **23** may be used to elevate the temperature of the manifold **12**, which, in turn, elevates the temperature of the pump **40** in each pump assembly **20**. The thermal isolation region **70** minimizes thermal transfer from the pump **40** to the drive motor unit **60**, thereby minimizing the effect of temperature on the electronic components in the drive motor unit **60**. Exposing the electronic components in the drive motor unit **60** to a sufficiently elevated temperature may damage the electronic components, which may render the drive motor unit **60** inoperable.

The drive motor unit **60** includes a motor **62**, an output drive shaft **66**, and one or more connectors (not shown) that are coupled to a power source (not shown). The drive motor unit **60** is coupled to a gear assembly **67**, which may include any type of gears as desired that transfer rotational motion from an output drive shaft **66** of the motor to the input drive shaft (not shown) of the pump to attain the desired rotational speed. In one embodiment, the gear assembly **67** includes a planetary gear train. The output drive shaft **66** has a drive axis A about which the output drive shaft **66** rotates.

Referring back to FIGS. **3** and **4**, the pump assembly **20** may be mounted to the manifold **12** in a number of different configurations. In one embodiment, the pump assembly **20** is mounted to the manifold **12** so that the bottom surface **41** of the pump **40**, which includes an inlet **52** and an outlet **54**, faces the manifold **12** at a location that is spaced apart from and located between the first and second side surfaces **34***a* and **34***b*. In this configuration, the drive motor axis A does not intersect either the first side surface **34***a* or the second side surface **34***b* of the applicator **10**. Rather, the pump assembly **20** is positioned on the manifold **12** such that the drive motor axis A of the drive motor unit **60** may lie in a plane Y that is parallel to the first plane P**1**, in which the first side surface **34***a* lies, as described above. The plane Y may also be parallel to the second plane P**2**, in which the second side surface **34***b* lies. Each pump assembly **20***a*-**20***g* has a respective axis A that lies within a respective plane that may be parallel to the first plane P**1** and/or the second plane P**2**. Further, when mounted to the manifold **12**, the pump assemblies **20***a*-**20***f* can be positioned such that the inlets **52** of each of the pump assemblies **20***a*-**20***f* are positioned above the outlets **54** along the transverse direction **6**. However, the recirculation pump assembly **20***g* can be mounted to the manifold **12** such that the outlet **54** is positioned above the inlet **52** along the transverse direction **6**.

Continuing with FIGS. **3** and **4**, the pump assembly **20** is positioned on the manifold **12** such that the drive motor axis A is oriented in any particular direction within plane Y. For example, the pump assembly **20** can be positioned on the manifold **12** such that the drive motor axis A lies within plane Y and is angularly offset with respect to plane X. For instance, the pump assembly **20** can be positioned on the manifold **12** such that the drive motor axis A defines an angle θ with plane X. The angle θ can be any angle as desired. In one embodiment, the angle θ is an acute angle. Alternatively, the angle θ can be an obtuse angle, an angle greater than 180 degrees, or substantially 90 degrees.

Referring to FIGS. **6-10**, the pump **40** includes a housing assembly **42** and a gear assembly **50** contained within the housing assembly **42**. Alternatively, more than one gear assembly **50** may be contained within the housing assembly **42**. The housing assembly **42** further includes an inlet **52** that is configured to receive adhesive from the manifold segment **22**, as well as an outlet **54** for discharging adhesive back into the manifold segment **22**. In accordance with the embodiment illustrated in FIGS. **6-10**, the inlet **52** and the outlet **54** of the pump **40** are defined by a bottom surface **41** of the pump **40** and are oriented in a direction that is parallel to the drive motor axis A of the drive motor unit **60**.

The housing assembly **42** comprises an upper plate **44***a*, a lower plate **44***b*, and a central block **46**. The upper and lower plates **44***a* and **44***b* are spaced from each other along a direction that is aligned with a drive axis A of the drive motor unit **60**. The lower plate **44***b* defines a bottom surface **41**, through which the drive axis A may extend. The upper plate **44***a*, the central block **46**, and the lower plate **44***b* are coupled together with bolts **48**. The upper plate **44***a* has a plurality of bores **49***a* that are configured to receive the bolts **48**, the central block **46** has a plurality of bores **49***b* that are configured to receive the bolts **48**, and the lower plate **44***b* has a plurality of bores **49***c* that are configured to receive the bolts **48**. The bolts **48**, bores **49***a*, bores **49***b*, and bores **49***c* may be threaded, such that the bores **49***a-c* are capable of threadedly receiving the bolts **48**.

The central block **46** has an internal chamber **56** that is sized to generally conform to the profile of the gear assembly **50**. In one embodiment, the gear assembly **50** includes a driven gear **55***a* and an idler gear **55***b*, which are known to a person of ordinary skill in the art. The driven gear **55***a* is coupled to the output drive shaft **66** of the drive motor unit **60** such that rotation of the output drive shaft **66** rotates the driven gear **55***a*, which, in turn, rotates the idler gear **55***b*. The driven gear **55***a* rotates about a first axis A_1, while the idler gear **55***b* rotates about a second axis A_2. In FIG. **10**, the first axis A_1 is illustrated as coaxial with the drive motor axis A. However, it is also contemplated that the first axis A_1 may be offset from the drive motor axis A. The gear assembly **50** may include an elongate gear shaft (not shown) that is coupled to an end of the output drive shaft **66** via a coupling (not shown). The gear shaft extends into the driven gear **55***a*, and is keyed to actuate the driven gear **55***a*. A seal member (not shown), such as a coating and/or an encasement, can be placed around the elongate gear shaft to facilitate sealing of the gear assembly **50** and internal chamber **56**.

In use, rotation of the driven gear **55***a* and the idler gear **55***b* drives adhesive in the pump **40** from a first section **58***a* of the internal chamber **56** to a second section **58***b* of the internal chamber **56**. The adhesive is then routed from the second section **58***b* of the internal chamber **56** to the outlet **54**. In accordance with the illustrated embodiment, the driven gear **55***a* has a diameter D_1 and a length L_1, where the length L_1 may be greater than the diameter D_1. Likewise, the idler gear **55***b* has a diameter D_2 and a length L_2, where the length L_2 may be greater than the diameter D_2. While a gear assembly **50** with two gears is shown, the pump can have a gear assembly that has any number of gear configurations to produce the desired flow rate of adhesive through the pump **40**. In these configurations, the central block **46** can be segmented to support gear stacking. In one embodiment, a plurality of gear assemblies (not shown) can be stacked along the pump input shaft. In this embodiment, the gear assemblies can have different outputs that are combined into a single output stream. In another embodiment, the gear assemblies have different outputs that can be kept separate to provide multiple outputs through additional porting in the lower plate **44***b* and the manifold **12**.

Continuing with FIGS. **6-10**, the thermal isolation region **70** is defined by a thermal isolation plate **72** and a gap **74** that extends from the thermal isolation plate **72** to the housing assembly **42**. The pump assembly **20** includes bolts **75** that couple the thermal isolation plate **72** to the top of the housing assembly **42** so that the gap **74** is formed between the housing assembly **42** and the thermal isolation plate **72**. The thermal isolation plate **72** can include a plurality of spacers **76** that are disposed around the bolts **75** and are positioned between a surface of the thermal isolation plate **72** and the upper plate **44***a* of the housing assembly **42**. The spacers **76** may be monolithic with the thermal isolation plate **72**, or may be separable from the thermal isolation plate **72** such that the gap **74** may be adjustable. The spacers **76** may extend inward from the upper plate **44***a* to ensure the output drive shaft **66** and the driven gear **55***a* are aligned. The thermal isolation plate **72** functions to inhibit the transfer of heat from the pump **40** to the drive motor unit **60**. To do this, the thermal isolation plate **72** and the spacers **76** are made of a material that has a lower thermal conductivity than the adhesives that form the components of the housing assembly **42** and an outer casing **61** of the drive motor unit **60**. Furthermore, the spacers **76** separate the thermal isolation plate **72** and the housing assembly **42** such that the thermal isolation plate **72** and the housing assembly **42** has the gap **74**, which minimizes direct contact between the housing assembly **42** and the drive motor unit **60**.

Referring to FIG. **3**, each of the pump assemblies **20***a*-**20***g* is removably attached to the manifold **12**. In one embodiment, each pump assembly **20** is secured to a plate **28** via a fastener **27**. The plate **28** is attached at one end to the first end plate **24** via a fastener **29**, and at the opposite end to the second end plate **26** via another fastener **29**. The fasteners **29** can also attach the plate **28** to one of the manifold segments **22**. Fasteners **27** may be threaded, such that removing a pump assembly **20** from the manifold **12** requires unscrewing fastener **27** from the pump assembly **20** and removing the pump assembly **20** from the manifold **12**. However, other methods of releasably attaching the pump assemblies **20** to the manifold **12** are contemplated, such as a slot and groove system, snap fit engagement, etc. Because the pump assemblies **20** may be releasably coupled to the manifold **12** in the above manner, a particular pump assembly **20** may be individually replaced without completely disassembling the entire applicator **10**. Pump assemblies **20** may require replacement for a variety of reasons, including cleaning, damage, or changed adhesive pumping conditions or requirements.

FIGS. **11-12** illustrate another embodiment of the present invention. FIG. **13** shows a pump assembly **120** that is similar in most aspects to the pump assembly **20** shown in FIGS. **1-9** and described above. However, the pump assembly **120** has an inlet **152** and an outlet **154** that are oriented differently than the inlet **52** and outlet **54** of the pump assembly **20**. The pump assembly **120** is configured to supply heated liquid to the manifold **12** at a given volumetric flow rate. Each pump assembly **120** includes a pump **140** and a dedicated drive motor unit **160** that powers the pump **140**. The pump assembly **120** also includes a thermal isolation region **170** between the pump **140** and the drive motor unit **160**. The thermal isolation region **170** is defined by a thermal isolation plate **172** and a gap **174** that extends from the thermal isolation plate **172** to the housing assembly **142**. The thermal isolation region **170** minimizes thermal transfer of heat generated by the pump **140** to the drive motor unit **160**, thereby minimizing the effect of temperature on the electronic components in the drive motor unit **160**. The dedicated drive motor unit **160** and thermal isolation region **170** are the same as the drive motor unit **60** and the thermal isolation region **70** described above and illustrated in FIGS. **6-9**.

Continuing with FIGS. **11-12**, the drive motor unit **160** includes a motor **162**, an output drive shaft **266**, and connectors (not shown) that are coupled to a power source (not shown), as well as the control system **110**. The drive shaft **166** has a drive axis B about which the drive shaft **166** rotates. When the pump assembly **120** is coupled to the manifold **12**, the drive axis B may intersect and may be angularly offset with respect to the plane X that is perpendicular to the plane Y. In this configuration, the drive motor axis B does not intersect either the first side surface **34***a* or the second side surface **34***b* of the manifold **12**. Additionally, the drive motor axis B does not intersect the bottom surface **30** of the manifold **12**. Rather, the pump assembly **120** is positioned on the manifold **12** so that drive motor axis B of the drive motor unit **160** lies in a plane Y that is parallel to the first plane **P1** and/or the second plane **P2** of the first side surface **34***a* and the second side surface **34***b*, respectively.

The pump **140** defines a bottom surface **141** and a side surface **143**, and includes a housing assembly **142** and one or more gear assemblies **150** contained within the housing assembly **142**, an inlet **152** for receiving liquid from the manifold **12**, and an outlet **154** for discharging liquid back into the manifold **12**. In accordance with the illustrated embodiment, the inlet **152** and the outlet **154** of the pump **140** are disposed on the side surface **143** of the pump **140**, such that the inlet **152** and outlet **154** are oriented in a direction that is perpendicular to the drive motor axis B of the drive motor unit **160**.

Continuing with FIGS. **13-14**, the flow path of adhesive through the applicator **10** will be described. The flow of adhesive through any particular element is represented by solid arrows that appear in the associated figures. The applicator **10** may be attached to a melter **3** by a hose **5**, which attaches to the input connector **14** (as shown in FIG. **1**). The adhesive flows from the melter **3**, through the hose **5**, through the input connector **14**, and into the supply channel **200** defined by the manifold **12** of the applicator **10**. The supply channel **200** may extend from the first side surface **34***a*, through each of the manifold segments **22***a*-**22***c*, and to the second side surface **34***b*. However, the supply channel **200** may not necessarily extend entirely from the first side surface **34***a* to the second side surface **34***b*, but may terminate at an interior location between the first and second side surfaces **34***a* and **34***b*. Additionally, the supply channel **200** may extend between other combinations of surfaces of the manifold **12** as desired.

The manifold **12** includes a pressure release valve **17** that regulates flow in a pressure release channel (not shown) that is in fluid communication with the supply channel **200**. The pressure release valve **17** is depicted as being positioned at the front surface **36** of the manifold **12**. However, the pressure release valve can be positioned on any surface of the manifold **12** as desired. The pressure release valve **17** is capable of being alternated between an open and closed position. When an operator desires to relieve adhesive pressure within the supply channel **200**, the pressure release valve **17** is switched from the closed to open positions. In the open position, adhesive flows from the supply channel **200**, through the pressure release channel, and out of the applicator **10** through a drain (not shown). Pressure relief may be desired when the operator is about to commence a service or maintenance operation of the applicator **10**.

As the supply channel **200** extends through the manifold **12**, it supplies adhesive to each of the pump assemblies **20***a*-**22***f*, with the exception of the designated recirculation pump assembly **20***g*. For simplicity, a cross-section of the applicator **10** shown in FIGS. **13-14** only shows the supply of adhesive to one pump assembly **20** and one dispensing module **16**. However, the supply channel **200** may supply each additional pump assembly **20** and dispensing module **16** similarly. The manifold segment **22** defines a first segment input channel **204**, which extends from the supply channel **200** to a diverter plate **208**, which may be positioned on the applicator **10** between the pump assembly **20***d* and the manifold segment **22***b*. The diverter plate **208** may be removably coupled to the applicator **10**, and may define a variety of passages for carrying adhesive from the manifold **12**, to the pump assemblies **20**, and back. For example, as shown in FIG. **13**, the diverter plate **208** defines a diverter input channel **212** that extends from the first segment input channel **204** to the inlet **52** of the pump assembly **20***d*. The diverter plate **208** may also define a diverter output channel **216** that extends from the outlet **54** of the pump assembly **20***d* to a second segment input channel **220**. However, the diverter plate **208** may include different channel configurations than those shown. The diverter plate **208** shown in FIG. **13** may function as one of many interchangeable diverter plates that may be used to variably route the adhesive through the applicator **10** as different dispensing operations require.

In the embodiment shown in FIGS. **13-14**, the adhesive flows from the supply channel **200**, through the first segment input channel **204**, through the diverter input channel **212**, and to the inlet **52** of the pump assembly **20**. The pump assembly **20** then pumps the adhesive out of the outlet **54** at a predetermined volumetric flow rate, which may be different than the volumetric flow rate of the adhesive upon entering the inlet **52** of the pump assembly **20**. From there, the adhesive flows through the diverter output channel **216**, through the second segment input channel **220**, and to a dispensing flow path **224**. The dispensing flow path **224** is defined by the lower portion **18***b* of the dispensing module **16**, which is received by the manifold segment **22**. The dispensing flow path **224** defines an upper section **224***a*, a lower section **224***c* opposite the upper section **224***a*, and a central section **224***b* disposed between the upper and lower sections **224***a* and **224***c*. The lower section **224***c* of the dispensing flow path **224** is in fluid communication with a nozzle channel **228**, which extends away from the dispensing flow path **224**. The upper section **224***a* of the dispensing flow path **224** is in fluid communication with a recirculation feed channel **232**, which extends from the upper section **224***a* of the dispensing flow path **224** to a recirculation channel **236**. The recirculation channel **236** will be discussed further below.

The lower portion **18***b* of the dispensing module **16** is the portion of the applicator **10** that directly interacts with the adhesive to control flow of the adhesive out of the applicator **10**. The applicator **10** may include a valve stem **260** that extends from an upper portion **18***a* of the dispensing module **16** that is opposite the lower portion **18***b* of the dispensing module **16**, to the lower portion **18***b* of the dispensing module **16**. The valve stem **260** may define a lower valve element **264** and an upper valve element **272** that is spaced from the lower valve element **264** along the valve stem **260**. The lower portion **18***b* of the dispensing module **16** may define a lower valve seat **268** that is configured to interact with the lower valve element **264** of the valve stem **260**, and an upper valve seat **276** that is spaced from the lower valve seat **268**, where the upper valve seat **276** is configured to interact with the upper valve element **272** of the valve stem **260**.

In operation, the valve stem **260** may alternate between a first position and a second position. When the valve stem **260** is in the first position, the dispensing module **16** is in an open configuration. When the valve stem **260** is in the second position, the dispensing module **16** is in a closed configuration. The upper and lower valve elements **272** and **264** may substantially face in opposite directions, such that each of the upper and lower valve elements **272** and **264** interact with the corresponding upper and lower valve seats **276** and **268** in different ones of the first position and second position. In FIGS. **13-14**, the upper valve element **272** is shown as facing away from the upper portion **18***a* of the dispensing module **16**, while lower valve element **264** is shown as facing toward the upper portion **18***a* of the dispensing module **16**. However, in another embodiment this relationship may be reversed, such that the upper valve element **272** faces toward the upper portion **18***a* of the dispensing module **16**, while the lower valve elements **264** faces away from the upper portion **18***a* of the dispensing module **16**. In one embodiment, in the first position, the valve stem **260** is lowered within the dispensing flow path **224**, such that the upper valve element **272** of the valve stem **260** engages the upper valve seat **276**, and the lower valve element **264** is spaced from the lower valve seat **268**. In this position, the engagement between the upper valve element **272** and the upper valve seat **276** blocks adhesive from flowing from the central section **224***b* of the dispensing flow path **224** to the upper section **224***a*. Rather, the lack of engagement between the lower valve element **264** and the lower valve seat **268** permits adhesive to flow from the central section **224***b* of the dispensing flow path **224** to the lower section **224***c*. As such, when the valve stem **260** is in the first position, adhesive flows from the second segment input channel **220**, through the central and lower sections **224***b* and **224***c* of the dispensing flow path **224**, and to the nozzle channel **228**. From the nozzle channel **228**, the adhesive then flows through the nozzle **21** and out of the applicator **10**. Accordingly, the first position of this embodiment is the position in which the applicator **10** applies adhesive to a substrate during a manufacturing operation.

In the second position, the valve stem **260** is raised within the dispensing flow path **224**, such that the upper valve element **272** of the valve stem **260** is spaced from the upper valve seat **276**, and the lower valve element **264** engages the lower valve seat **268**. In this position, the engagement between the lower valve element **264** and the lower valve seat **268** blocks adhesive from flowing from the central section **224***b* of the dispensing flow path **224** to the lower section **224***c*. Rather, the lack of engagement between the upper valve element **272** and the upper valve seat **276** permits adhesive to flow from the central section **224***b* of the dispensing flow path **224** to the upper section **224***a*. As such, in the second position, adhesive flows from the second segment input channel **220**, through the central and upper sections **224***b* and **224***a* of the dispensing flow path **224**, and to the recirculation feed channel **232**. From the recirculation feed channel **232**, the adhesive flows into the recirculation channel **236**. Though one dispensing module **16** and manifold segment **22** is shown in cross section in FIGS. **13-14**, each additional dispensing module **16** and manifold segments **22** may be similarly configured. Further, the valve stem **260** of each dispensing module **16** may be configured to be actuated between the first and second positions independent of any of the other valve stems **260**, such that at any time the valve stems **260** of the dispensing modules **16** may be in any combination of the first and second positions. Alternatively, any combination of the valve stems **260** may be configured to transition between the first and second positions in unison.

The ability to alternate the valve stem **260** between the particular first and second positions described above serves several purposes. One purpose is that, during an adhesive dispensing operation, a consistent flow of adhesive may not be required or desired. As such, an operator of the applicator **10** must be able to selectively actuate the dispensing modules **16** to both provide and prevent a flow of adhesive to the substrate. Transitioning the valve stem **260** from the first position to the second position blocks adhesive from exiting the applicator **10**, while transitioning the valve stem **260** from the second position to the first position allows adhesive to exit the applicator **10**. Another purpose of the alternative valve stem **260** described above relates to the pressure within the flow path of the adhesive. When the valve stem **260** is in the first position, the adhesive is permitted to flow through the gap between the lower valve element **264** and the lower valve seat **268**, and exit the applicator **10** through the nozzle **21**. However, when the valve stem **260** is in the second position, the adhesive cannot flow through this gap. As such, the potential exists for unused adhesive to back up within the dispensing flow path **224** and/or the second segment input channel **220**. This back-up can cause pressure to build up within the applicator **10**. This pressure, upon the next transition of the valve stem **260** from the second position to the first position, can cause a pattern deformation, such as hammerhead, of the adhesive on the substrate.

The inclusion of the recirculation channel **236** in the applicator **10** helps alleviate this issue. When the valve stem **260** is in the second position, the ability of the adhesive to flow from the central section **224***b* of the dispensing flow path **224** to the upper section **224***a*, and through the recirculation feed channel **232** to the recirculation channel **236** provides the adhesive the ability to escape the dispensing flow path **224**. This may alleviate any pressure build-up that could occur when the valve stem **260** is in the second position, thus aiding in standardizing the flow of adhesive through the nozzle **21** (such as through preventing adhesive hammerhead on the substrate) when the valve stem **260** is in the first position. However, the addition of the recirculation channel **236** alone may not fully rectify this issue. Adhesive flowing through recirculation channel **236** inherently creates some amount of pressure within the recirculation channel **236**. In a configuration where the recirculation channel **236** directs the adhesive back to the inlet **52** of the pump assembly **20**, or to supply tank that supplies the adhesive to the applicator **10**, a differential may exist between the pressure of the adhesive flowing through the recirculation channel **236** and the adhesive flowing to the dispensing modules **16***a*-**16***f* when the valve stem **260** is in the second position. This pressure differential may cause the flow rate of the adhesive flowing through the nozzle **21** to be inconsistent, as the volume of material entering the recirculation channel **236** may vary over time, depending upon which of the dispensing modules **16***a*-**16***f* have valve stems **260** in the second position at a particular moment.

FIG. **15** illustrates a process flow diagram depicting a system for managing the flow of adhesive through the recirculation channel **236** so as to actively control this pressure differential. Solid lines and arrows indicate the flow of adhesive through the applicator **10**, and dashed lines and arrows indicate the transfer of information. The adhesive flows from an adhesive supply (not shown), through a hose (not shown) that is coupled to the input connector **14** (FIG. **1**) of the applicator **10**, and into the supply channel **200**. As the adhesive flows through the supply channel **200**, it flows at a first pressure. To detect the first pressure, a first pressure sensor **302** may be disposed within the supply channel **200**. The first pressure sensor **302** may be any type of pressure sensor that is capable of measuring the pressure of a fluid, such as, for example, a pressure transducer. The first pressure sensor **302** may measure the first pressure of the adhesive as it flows through the supply channel **200** to the pump assembly **20**. The adhesive then flows through dispensing pumps **20***a*-**20***f*, which subsequently pump the adhesive to the dispensing modules **16***a*-**16***f*. The applicator **10** can include a plurality of pressure sensors **310***a*-**310***f*, where each pressure sensor **310***a*-**310***f* can be incorporated into or in communication with the output of a respective one of the pump assemblies **20***a*-**20***f*. For example, the pressure sensor **310***a* can be in communication with the output of the pump assembly **20***a*, the pressure sensor **310***b* can be in communication with the output of the pump assembly **20***b*, etc. Though any number of pressure sensors **310***a*-**310***f* is contemplated, the number of pressure sensors **310***a*-**310***f* can generally correspond to the number of pump assemblies **20***a*-**20***f*. In one embodiment, the pressure sensors **310***a*-**310***f* can be pressure sensors configured to detect the pressure of the adhesive pumped by a corresponding one of the pump assemblies **20***a*-**20***f* to the corresponding one of the dispensing modules **16***a*-**16***f*. The pressure sensors **310***a*-**310***f* can be pressure transducers or any other type of pressure sensor capable of measuring the pressure of fluid.

When the valve stems **260** of the dispensing modules **16***a*-**16***f* are in the first position, the adhesive flows out of the nozzles **21**. Alternatively, when the valve stems **260** are in the second position, the adhesive flows into recirculation channel **236**. The adhesive from each of the dispensing modules **16***a*-**16***f* that flows into the recirculation channel **236** is directed to the recirculation pump assembly **20***g*. As the adhesive flows through the recirculation channel **236**, it flows at a second pressure. To detect the second pressure, a second pressure sensor **304** may be disposed within the recirculation channel **236**. The second pressure sensor **304**, like the first pressure sensor **302**, may be any type of pressure sensor that is capable of measuring the pressure of a fluid, such as a pressure transducer.

Upon measuring the first and second pressures, the first and second pressure sensors **302** and **304** transmit the first and second pressures to a controller **7**. Further, each of the pressure sensors **310***a*-**310***f* can be in signal communication with the controller **7** and transmit the detected pressure of the adhesive pumped from the pump assemblies **20***a*-**20***f* to the controller **7**. The controller **7** may be connected to the applicator **10** through a signal connection **8**, which may comprise a wired and/or wireless connection. The controller **7** may include one or more processors, one or more memories, input/output components, and a human-machine interface (HMI) device **7***a*, and may comprise any device capable of including those components. The HMI interface **7***a* may include a touchscreen, mouse, keyboard, buttons, dials, etc. The input/output components may be configured to receive signals containing the first and second pressures from the first and second pressure sensors **302** and **304** via the signal connection **8**. The controller **7**, using the pressure information received from the first and second pressure sensors **302** and **304** and the pressure sensors **310***a*-**310***f*, may actively direct the operation of the recirculation pump assembly **20***g*. Accordingly, the pump assembly **20***g* is operable independent of the other pump assemblies **20***a*-**20***f*.

The recirculation pump assembly **20***g* functions to pump adhesive from the recirculation channel **236** back to the supply channel **200**. In controlling the recirculation pump assembly **20***g*, the controller **7** actively controls the flow rate at which the recirculation pump assembly **20***g* pumps the adhesive through the recirculation channel **236** by automatically adjusting the speed (RPM) of the drive motor. As a result, the controller **7** can direct the recirculation pump assembly **20***g* to pump the adhesive at a flow rate sufficient to control the pressure differential between the recirculation channel **236** and the pressure at which the pump assemblies **20***a*-**20***f* pump the adhesive to the respective dispensing modules **16***a*-**16***f* as detected by each of the respective pressure sensors **310***a*-**310***f*. In one embodiment, the recirculation pump assembly **20***g* can substantially equalize the second pressure of the adhesive flowing through the recirculation channel **236** with the pressure at which the pump assemblies **20***a*-**20***f* pump the adhesive to the respective dispensing modules **16***a*-**16***f* as detected by each of the respective pressure sensors **310***a*-**310***f*. While the recirculation channel **236** itself reduces pressure differential between material recirculated from the dispensing modules **16***a*-**16***f* and material entering the dispensing modules **16***a*-**16***f*, the recirculation pump assembly **20***g* functions to actively control the differential between the pressure of adhesive flowing through the recirculation channel **236** and pressure of adhesive flowing to the dispensing modules **16***a*-**16***f*, which can aid in increasing continuity in the volumetric output of the adhesive that is applied to a substrate via nozzles **21**. Though the controller **7** may be capable of autonomously controlling operation of the recirculation pump assembly **20***g* to equalize these pressures, an operator of the applicator **10** may optionally be able to manually control operation of the recirculation pump assembly **20***g* through the user inputs received by the controller **7**, or by running a program stored in the memory of the controller **7**. Further, in addition to pressure equalization, in certain embodiments it can be desirable to utilize the recirculation pump assembly **20***g* to create a nonequal relationship between the pressure within the recirculation channel **236** and the adhesive provided to the respective dispensing modules **16***a*-**16***f* so as to ensure optimal pattern and flow conditions for particular adhesives or substrates.

Though shown in FIGS. **1**-**5** as being mounted to the manifold **12**, the recirculation pump assembly **20***g* may be spaced from the manifold **12**. In this configuration, the recirculation pump assembly **20***g* is connected to the manifold **12** via one or more hoses, allowing the pump assembly **20***g* to receive adhesive from and pump adhesive to the manifold **12**. For example, one hose may direct adhesive from the recirculation channel **236** to the recirculation pump assembly **20***g*, while a second hose may direct adhesive from the recirculation pump assembly **20***g* to the supply channel **200**.

The presence of the dedicated recirculation pump assembly **20***g* to actively regulate pressure of adhesive flowing through the recirculation channel **236** of the applicator **10** may simplify the overall construction of the applicator **10**. For example, with the recirculation pump assembly **20***g*, a second hose that connects the recirculation channel **236** to the adhesive supply (not shown) is not required. Additionally, the applicator **10** becomes better adapted to accommodating different applications. As a client's requirements change, the recirculation pump assembly **20***g* adapts to likewise actively regulate the pressure within the applicator

10, such that the pressure differential between the recirculation channel 236 and the adhesive pumped to the dispensing modules 16*a*-16*f* remains minimal or nonexistent, regardless of application.

The presence of the recirculation pump assembly 20*g* further aids in maintaining tighter tolerances in the flow rate of adhesive exiting the applicator 10 through nozzles 21. Despite the intermittent operation of the dispensing modules 16, actively regulating the pressure of the adhesive in the recirculation channel 236 allows for a controllable and consistent flow rate of adhesive exiting the applicator 10, as opposed to the flow rate being simply a function of the pressure of adhesive in the recirculation channel 236 and adhesive pumped to the dispensing modules 16*a*-16*f* at any given time. This consistent flow rate helps reduce costs incurred during a dispensing operation, particularly in the substrates to which the adhesive is applied. Though some substrates may be more accommodating of the effects of pattern deformations of the adhesive applied to the substrate, some substrates are more sensitive to such variations in adhesive flow. These differences in flow rates can result in substrate deformation or "burn through." By actively regulating the adhesive pressure using recirculation pump assembly 20*g* to ensure a consistent flow rate, wasted substrate can be avoided, thus reducing costs for the operator of the applicator 10.

Continuing with FIG. 16, a schematic diagram of a dispensing system 1 for controlling the operation of the pump assemblies 20*a*-20*g* is depicted, where solid lines indicate adhesive flow and dashed lines indicate signal transmission. Though only pump assemblies 20*a*, 20*b*, and 20*g* are shown in FIG. 16, the features and functionality described below related to pump assemblies 20*a*, 20*b*, and 20*g* are equally applicable to each of pump assemblies 20*a*-20*g*. Components that comprise the applicator 10 are schematically shown within the dashed line labeled with reference numeral 10. As depicted, adhesive is melted by the melter 3 and directed through a filter 13 to the supply channel 200 of the applicator 10, which is configured to provide the adhesive to each of the plurality of pump assemblies 20*a*-20*f*. The applicator 10 can include the first pressure sensor 302 that is configured to measure a pressure of the adhesive flowing through the supply channel 200 and send a signal to the controller 7 through the signal connection 8 that is representative of that pressure. The pressure sensor 302 can be a pressure transducer, though it is contemplated that any conventional type of pressure sensor that is suitable for measuring the pressure of a fluid can be utilized. Pressure transducers comprise devices that convert pressure into an analog electrical signal. Various types of pressure transducers can be utilized, such as a capacitive pressure transducer, digital output pressure transducer, voltage/current output pressure transducer, etc.

After the adhesive passes through the supply channel 200, it can be directed to each of the pump assemblies 20*a*-20*f*. As described above, each of the pump assemblies 20*a*-20*f* is configured to pump the adhesive to a respective one of the dispensing modules 16*a*-16*f*. As such, each of the pump assemblies 20*a*-20*f* can pump the adhesive at a respective operating speed that can be the same or different than any of the other pump assemblies 20*a*-20*f*. As stated above, the applicator 10 can include a plurality of pressure sensors 310*a*-310*f* configured to detect the pressure of the adhesive pumped to the respective dispensing modules 16*a*-16*f* and send signals to the controller 7 through the signal connection 8 that is representative of those pressures. Accordingly, the operating speed of any of the pump assemblies 20*a*-20*f* can be individually adjusted by the controller 7, which is in signal communication with each of the pump assemblies 20*a*-20*f*. The controller 7 can be configured to detect the current draw of each of the plurality of pump assemblies 20*a*-20*f*. The current draw from each of the pump assemblies 20*a*-20*g* may fluctuate throughout a dispensing process as the pump assemblies 20*a*-20*g* are forced to draw more or less current in order to maintain a particular operating speed. This fluctuation in current draw can be indicative to a user of a change within the applicator 10, such as changed viscosity in the material.

After providing the material to the dispensing modules 16*a*-16*f*, each of the dispensing modules 16*a*-16*f* is configured to selectively dispense the material from the applicator 10. In particular, as described above, each of the dispensing modules 16*a*-16*f* includes a respective valve stem 260 that is configured to transition back and forth along a linear path, also referred to as a valve stroke, to control flow of adhesive from each of the plurality of dispensing modules 16*a*-16*f*. Like the pump assemblies 20*a*-20*f*, the dispensing modules 16*a*-16*f* can be affected by a change in the dispensing system 1, such as a clog or property change in the material flowing through the dispensing system 1. In particular, the length of time required for each valve stem 260 to travel through a complete stroke length may be affected. To monitor this, the applicator 10 can include a plurality of position sensors 314*a*-314*f* configured to measure an instantaneous position of a valve stem 260 of a corresponding one of the dispensing modules 16*a*-16*f* and send a signal to the controller 7 through the signal connection 8 that is representative of the instantaneous position. The positions sensors 314*a*-314*f* can be fiberoptic sensors configured to measure the change in intensity of light reflected from a component connected to the respective valve stems 260, though it is contemplated that any conventional type of position sensor that is suitable for measuring the instantaneous position of the valve stems 260 can be utilized. Though only position sensors 314*a*, 314*b* are shown, the applicator 10 can include a position sensor 314*a*-314*f* that corresponds to each of the dispensing modules 16*a*-16*f*. For example, the position sensor 314*a* can be configured to measure the instantaneous position of the valve stem 260 of the dispensing module 16*a*, the position sensor 314*b* can be configured to measure the instantaneous position of the valve stem 260 of the dispensing module 16*b*, etc. The valve stroke may fluctuate through a dispensing process as the fluid properties of the adhesive changes, clogs or dried material builds up within the applicator 10, etc.

As described previously, during periods in which the dispensing modules 16*a*-16*f* are not dispensing material from the applicator 10, they can direct the material to a recirculation channel 236. This recirculation channel 236 can direct this recirculated material from each of the dispensing modules 16*a*-16*f* back to the supply channel 200. Like the first pressure sensor 302 associated with the supply channel 200, the applicator 10 can include a second pressure sensor 304 that is configured to measure a pressure of the adhesive flowing through the recirculation channel 236 and send a signal to the controller 7 through the signal connection 8 that is representative of that pressure. The second pressure sensor 304 can be a pressure transducer, though it is contemplated that any conventional type of pressure sensor that is suitable for measuring the pressure of a fluid can be utilized.

As described above, the recirculation pump assembly 20*g* pumps the material through the recirculation channel 236 and otherwise control the flow of the adhesive through the recirculation channel 236. The controller 7 can be in signal communication with the recirculation pump assembly **20***g* through the signal connection **8** and be configured to detect the current draw of the recirculation pump assembly **20***g*. The current draw from the recirculation pump assembly **20***g* may fluctuate throughout a dispensing process as the recirculation pump assembly **20***g* is forced to draw more or less current in order to maintain a particular recirculation material flow rate. This fluctuation in current draw can be indicative to a user of a change within the applicator **10**, such as changed viscosity in the material or a clog within the recirculation channel **236**.

The applicator **10** can also include pump sensors **311***a*-**311***f* and a recirculation pump sensor **311***g* configured to detect other aspects of the pump assemblies **20***a*-**20***f* and recirculation pump assembly **20***g*, respectively, other than the current draw in order to accurately monitor the flow of material. For example, the pump sensors **311***a*-**311***f* and recirculation pump sensor **311***g* can include sensors that measure motor torque and operating speed of the pump assemblies **20***a*-**20***f* and recirculation pump assembly **20***g* or the pressure of the adhesive exiting the pump assemblies **20***a*-**20***f* and recirculation pump assembly **20***g*, and likewise send a signal to the controller **7** that is representative of these various measurements. As such, pump sensors **311***a*-**311***f* and recirculation pump sensor **311***g* can be optical encoders or Hall effect sensors. Measurement of these factors can be performed by the pump sensors **311***a*-**311***f* and recirculation pump sensor **311***g* on a continuous or intermittent basis, which may be selectable or altered by the operator.

Continuing with FIG. **16**, as previously described the applicator **10** can include a plurality of thermal elements **23** for heating the manifold **12** of the applicator **10**, and likewise the material flowing through the applicator **10**. The thermal elements **23** can be cartridge style, Kapton wire, cast-in, or induction coil heating elements, though any type of conventional heater is contemplated. The thermal elements **23** can function to maintain the material at an elevated temperature, which aids in maintaining the fluid properties of the material and thus allowing it to easily flow through the applicator. Many conventional applicators have a single thermal element, and thus only define a single zone of heating. However, the thermal elements **23** can create multiple heating zones throughout the applicator **10** so as to allow more localized and precise control over heating within specific parts of the applicator **10**. The thermal elements **23** can be positioned at various locations throughout the applicator **10** such that the material is evenly heated as it flows through the applicator **10**. Though only two thermal elements **23** are schematically shown, the applicator **10** can include one, three, four, or five or more thermal elements **23**. The applicator **10** can also include plurality of heat sensors **318**, where each of the heat sensors **318** corresponds to a respective one of the plurality of thermal elements **23**. The heat sensors **318** can be in fluid communication with the material so as to detect a temperature of the material in the vicinity of the corresponding thermal element **23** and transmit a heat signal to the controller **7** that is representative of the temperature of the material. The heat sensors **318** can be nickel or platinum resistance temperature detectors or thermocouples, though any type of conventional heat sensor is contemplated. The controller **7** can utilize the measurements from the heat sensors **318** to determine a property of the material, such as the material's viscosity.

The controller **7** can be configured to receive signals from the first and second pressure sensors **302**, **304**, the pressure sensors **310***a*-**310***f*, the position sensors **314***a*-**314***f*, and heat sensors **318** that correspond to various parameters of the adhesive and components within the applicator **10** in order to determine how to control the pump assemblies **20***a*-**20***f*, recirculation pump assembly **20***g*, and thermal elements **23**. In particular, the controller **7** can determine an adjustment to the operating speed of each of the plurality of pump assemblies **20***a*-**20***f* individually based on their respective current draws, and subsequently direct each of the plurality of pump assemblies **20***a*-**20***f* to individually adjust their operating speed. An increase or decrease in current draw can indicate to the operator that a change within the applicator **10**, such as a change in properties of the adhesive, has occurred. As a result, the operator may find it desirable to increase or decrease the operating speed of any of the pump assemblies **20***a*-**20***f* to maintain dispensing consistency.

An adjustment to the operating speed of any of the pump assemblies **20***a*-**20***f* can be automatically be made by the controller **7** upon detecting a deviation between an intended or preset current draw and the actual current draw detected by the controller **7**. Alternatively, the controller **7** can be configured to direct each of the plurality of pump assemblies **20***a*-**20***f* to individually adjust their operating speeds when their respective current draws are outside a predetermined range. For example, this range can be about plus or minus 0.1-10 Amps, though a typical value can be about 0.25 Amps. This range therefore defines an acceptable range within which the current draw may vary. Such a range can be preselected by the operator or automatically determined by the controller **7** based upon factors such as the material to be dispensed, the dispensing operation to be performed, the substrate onto which the material will be dispensed, etc. To preselect the range, the HMI device **7***a* can be configured to receive a user input that allows an operator to manually select the predetermined range. The operator may also be able to freely adjust the range at any time throughout a dispensing process. In addition to adjusting the operating speeds of the plurality of pump assemblies **20***a*-**20***f* when their respective current draws are outside the predetermined range, the HMI device **7***a* can also be configured to produce an alert when the current draw of at least one of the plurality of pump assemblies **20***a*-**20***f* is outside the predetermined range. The alert can notify the operator of the issue within the applicator **10** and inform the operator that human intervention may be required in order to rectify the issue. Likewise, as the controller **7** can be configured to direct each of the plurality of pump assemblies **20***a*-**20***f* to individually adjust their operating speeds when their respective current draws are outside a predetermined range, the controller **7** can also be configured to direct each of the plurality of pump assemblies **20***a*-**20***f* to maintain their operating speeds when their respective current draws are within a predetermined range. This allows the pump assemblies **20***a*-**20***f* to continue operating despite small variations in current draw that may be indicative of issues inconsequential enough to not appreciably affect the quality or consistency of the dispensed material.

Though adjustments to the pump assemblies **20***a*-**20***f* have been specifically described, the recirculation pump assembly **20***g* can be similarly operated. The controller **7** is configured to determine an adjustment to the operating speed of the recirculation pump assembly **20***g* based on the current draw from the recirculation pump assembly **20***g* as detected by the controller **7**. An adjustment to the operating speed of the recirculation pump assembly **20***g* can be automatically made by the controller **7** upon detecting a deviation between an intended or preset current draw and the actual current draw measured by the controller **7**, or when the measured current draw is outside a predetermined operating range. Likewise, the controller **7** can be configured to direct the recirculation pump assembly **20***g* to maintain its operating speed when its current draw is within the predetermined range.

Though adjusting the operating speeds of the pump assemblies **20***a*-**20***f* and recirculation pump assembly **20***g* is discussed above with consideration of their respective current draws, the controller **7** can also take into consideration various other measurements when making these determinations. For instance, the controller **7** can be configured to determine the adjustment to the operating speed of each of the plurality of pump assemblies **20***a*-**20***f* and recirculation pump assembly **20***g* individually based on the pressure of the adhesive flowing through the supply channel **200**, as measured by the first pressure sensor **302**. Additionally, the controller **7** can be configured to determine the adjustment to the operating speed of each of the plurality of pump assemblies **20***a*-**20***f* and recirculation pump assembly **20***g* individually based on the pressure of the adhesive flowing through the recirculation channel **236**, as measured by the second pressure sensor **304**. Further, the controller **7** can be configured to determine the adjustment to the operating speed of each of the plurality of pump assemblies **20***a*-**20***f* and recirculation pump assembly **20***g* individually based on the pressure of the adhesive being pumped to the dispensing modules **16***a*-**16***f*, as measured by the pressure sensors **310***a*-**310***f*.

In addition to determining an adjustment to the operating speed of the pump assemblies **20***a*-**20***f* and the recirculation pump assembly **20***g*, the controller **7** can also process the measurements made by the various sensors and, through process of elimination and comparison to predetermined values, identify a specific defect that exists within the applicator **10**. For example, based on measurements performed by the pressure sensors **302**, **304**, the pressure sensors **310***a*-**310***f*, the position sensors **314***a*-**314***f*, and the heat sensors **318**, the controller **7** can identify specific problems occurring within the applicator **10**. When a particular issue has been identified by the controller **7**, the controller **7** can automatically perform adjustments to address the issue, as well as produce an alert via the HMI device **7***a* that indicates the problem to the operator and allows the operator to manually take corrective action. The alert can be a noise, vibration, light output, text notification, etc.

For example, when the speed of the pump assemblies **20***a*-**20***f* is below a predetermined setpoint, the current draw of the pump assemblies **20***a*-**20***f* increases, the pressure detected by the pressure sensors **310***a*-**310***f* increases, and a temperature sensed by any of the heat sensors **318** is below a setpoint, the controller **7** can recognize the cause of these factors as an increase in viscosity of the adhesive. Conversely, when the speed of the pump assemblies **20***a*-**20***f* is above a predetermined setpoint, the current draw of the pump assemblies **20***a*-**20***f* decreases, the pressure detected by the pressure sensors **310***a*-**310***f* decreases, and the temperature sensed by any of the heat sensors **318** is above a setpoint, the controller **7** can recognize the cause of these factors as a decrease in viscosity of the adhesive. When the current draw of the pump assemblies **20***a*-**20***f* increases and the pressure detected by the pressure sensors **310***a*-**310***f* increases, the controller **7** can recognize the cause of these factors as a clog in at least one of the nozzles **21**. When pressure detected by the pressure sensors **310***a*-**310***f* increases and the temperature sensed by any of the heat sensors **318** is below a setpoint, the controller **7** can recognize the cause of these factors as a failure of one or more of the thermal elements **23**. In a situation where the speed of the pump assemblies **20***a*-**20***f* is below a predetermined setpoint, the current draw of the pump assemblies **20***a*-**20***f* increases, and the pressure detected by the pressure sensors **310***a*-**310***f* decreases, the controller **7** can recognize the cause of these factors as a control failure in the pump assemblies **20***a*-**20***f*. In a situation where the speed of the pump assemblies **20***a*-**20***f* is both above and below a predetermined setpoint and the current draw of the pump assemblies **20***a*-**20***f* increases, the controller **7** can recognize the cause of these factors as a failure in the control of the pump assemblies **20***a*-**20***f*.

Additionally, when the current draw of the pump assemblies **20***a*-**20***f* decreases, the pressure detected by the pressure sensors **310***a*-**310***f* decreases, and the temperature sensed by any of the heat sensors **318** is above a setpoint, the controller **7** can recognize the cause of these factors as a failure in the control of the thermal elements **23**. When the current draw of the pump assemblies **20***a*-**20***f* decreases, the pressure detected by the pressure sensors **310***a*-**310***f* decreases, and the time that the valve stem **260** of any of the dispensing modules **16***a*-**16***f* is in the first position is above nominal as detected by the position sensors **314***a*-**314***f*, the controller **7** can recognize the cause of these factors as an increase in the interval duration that a solenoid (not labeled) is actuating the valve stem **260**. When the current draw of the pump assemblies **20***a*-**20***f* increases, the pressure detected by the pressure sensors **310***a*-**310***f* increases, and the time that the valve stem **260** of any of the dispensing modules **16***a*-**16***f* is in the first position is below nominal as detected by the position sensors **314***a*-**314***f*, the controller **7** can recognize the cause of these factors as a decrease in the interval duration that the solenoid is actuating the valve stem **260** or a failure of one of the valve stems **260**. In a situation where the current draw of the pump assemblies **20***a*-**20***f* decreases and the time that the valve stem **260** of any of the dispensing modules **16***a*-**16***f* is in the first position is above nominal as detected by the position sensors **314***a*-**314***f*, the controller **7** can recognize the cause of these factors as the wearing out of a component of the dispensing modules **16***a*-**16***f*. Though multiple problems that can occur within the applicator **10** and potential causes of these problems are described above, this listing is not intended to be exhaustive in both the type of problems the controller **7** can recognize and the potential causes of these problems.

Continuing with FIGS. **17**-**18**, a method **400** of controlling the dispensing of adhesive from the applicator **10** utilizing the components described in relation to FIG. **16** will be described. Method **400** includes step **402**, in which the adhesive is melted by the melter **3**. At any time during, before, or after the melter **3** melts the adhesive, the operator can manually input one or more predetermined acceptable ranges for the current draws of the pump assemblies **20***a*-**20***f* and/or the recirculation pump assembly **20***g* in step **406**. Alternatively, the acceptable range can be determined by the controller **7** based on the adhesive to be dispensed, the particular dispensing operation to be performed, etc. In step **412**, the melter **3** can provide the melted adhesive to the applicator **10**, such as through the hose **5**. Once the applicator **10** receives the melted adhesive, in step **414** the adhesive is directed through the supply channel **200** to the pump assemblies **20***a*-**20***f*. While the adhesive is being directed through the supply channel **200**, in step **418** the first pressure sensor **302** can measure the pressure of the adhesive flowing through the supply channel **200** and send a signal to the controller **7** that is representative of this measured pressure.

After step **418**, the adhesive is pumped to the dispensing modules **16***a*-**16***f* via the pump assemblies **20***a*-**20***f*, respectively in step **422**. In step **424**, the pressure sensors **310***a*-**310***f* can measure the pressure of the adhesive pumped by the pump assemblies **20***a*-**20***f* to the dispensing modules **16***a*-**16***f*. The pressure of the material flowing to the dispensing modules **16***a*-**16***f* can be utilized by the controller **7** to determine the adjustment to the operating speed of each of the plurality of pump assemblies **20***a*-**20***f* and the recirculation pump assembly **20***g*. As described above, the dispensing modules **16***a*-**16***f* are configured to selectively dispense the adhesive onto a substrate through reciprocation of the respective valve stems **260** of the dispensing modules **16***a*-**16***f*. When the valve stems **260** prevent adhesive from being applied to the substrates, the adhesive is pumped from the plurality of dispensing modules **16***a*-**16***f* through a recirculation channel **236** and back to the supply channel **200** via the recirculation pump assembly **20***g* in step **426**, which allows this adhesive to be recycled back through the applicator **10** and again supplied to the pump assemblies **20***a*-**20***f*. While the adhesive is being pumped through the recirculation channel **236** by the recirculation pump assembly **20***g*, in step **430** the second pressure sensor **304** can measure the pressure of the adhesive flowing through the recirculation channel **236** and send a signal to the controller **7** that is representative of this measured pressure. Like the pressure of the material flowing through the supply channel **200**, the pressure of the material flowing through the recirculation channel **236** as measured by the pressure sensor **304** can be utilized by the controller **7** to determine the adjustment to the operating speed of each of the plurality of pump assemblies **20***a*-**20***f* and the recirculation pump assembly **20***g* individually.

While the pump assemblies **20***a*-**20***f* are pumping the adhesive, in step **434** the controller **37** can measure the current draw from each of the pump assemblies **20***a*-**20***f*. The current draw of any of the pump assemblies **20***a*-**20***f* can fluctuate over time in response to changed conditions within the applicator **10** in order to maintain a consistent, set operating speed of each of the pump assemblies **20***a*-**20***f*. Following or concurrently with step **434**, in step **438** the pump sensors **311***a*-**311***f* can measure other parameters related to the pump assemblies **20***a*-**20***f*, such as motor torque, operating speed, and pump pressure of each of the plurality of pump assemblies **20***a*-**20***f*. After steps **434** and/or **438** are performed, in step **442** the controller **7** can determine an adjustment to an operating speed of each of the pump assemblies **20***a*-**20***f* based on their respective current draws. This adjustment can be determined individually by the controller for each of the pump assemblies **20***a*-**20***f*, and in addition to the current draw, can be based each of their unique measured motor torques, operating speeds, pump pressures, etc. In one embodiment, step **442** can include determining an adjustment to the operating speed of the pump assemblies **20***a*-**20***f* only when the current draw of any of the pump assemblies **20***a*-**20***f* are outside a predetermined range. As stated above, this range can be about plus or minus 0.1-10 Amps, though other ranges are contemplated. Likewise, step **442** can included maintaining the operating speed of each of the plurality of pump assemblies **20***a*-**20***f* when their respective current draws are within the predetermined range.

After the adjustment to the operating speed of the pump assemblies **20***a*-**20***f* has been determined in step **442**, in step **446** the controller **7** can direct the pump assemblies **20***a*-**20***f* to adjust their respective operating speeds individually in accordance with the determined adjustment. The operating speeds of any number of the pump assemblies **20***a*-**20***f* can be adjusted or maintained, depending on the measurements made by the first and second sensors **302**, **304** and pressure sensors **310***a*-**310***f*, as well as the determinations made by the controller **7**. At any time after step **442** is performed, and concurrently, before, or after step **446**, an alert can be produced in step **450** when the current draw of one of the plurality of pump assemblies **20***a*-**20***f* is outside the predetermined range. The alert can be produced by the HMI device **7***a* and take the form of a noise, vibration, light output, text notification, or any other type of conventional alert capable of notifying the operator that the current draw of one of the plurality of pump assemblies **20***a*-**20***f* is outside the predetermined range.

Continuing with FIG. **18**, while the recirculation pump assembly **20***g* is pumping the adhesive through the recirculation channel **236**, in step **454** the controller **7** can determine the current draw from the recirculation pump assembly **20***g* and simultaneously transmit a signal to the controller **7** that is indicative of the current draw of the recirculation pump assembly **20***g*. The current draw of any of the recirculation pump assembly **20***g* can fluctuate over time in order to maintain a consistent, set operating speed of the recirculation pump assembly **20***g* in response to changed conditions within the applicator **10**. Following or concurrently with step **454**, in step **458** the pump sensor **311***g* can measure other parameters related to the recirculation pump assembly **20***g*, such as motor torque, operating speed, and pump pressure of the recirculation pump assembly **20***g*. After steps **454** and/or **458** are performed, in step **462** the controller **7** can determine an adjustment to an operating speed of the recirculation pump assembly **20***g* based on its current draw. In addition to the current draw, this adjustment can be based on the motor torque, operating speed, pump pressures, etc. This adjustment can also be based on the pressures measured by the pressure sensors **310***a*-**310***f*. In one embodiment, step **462** can include determining an adjustment to the operating speed of the recirculation pump assembly **20***g* only when the current draw of the recirculation pump assembly **20***g* is outside a predetermined range. As stated above, this range can be about plus or minus 0.1-10 Amps, though other ranges are contemplated. Likewise, step **462** can include maintaining the operating speed of the recirculation pump assembly **20***g* when its current draw is within the predetermined range. After the adjustment to the operating speed of recirculation pump assembly **20***g* has been determined in step **462**, in step **466** the controller **7** can direct the recirculation pump assembly **20***g* to adjust its operating speed in accordance with the determined adjustment.

In step **470**, the heat sensors **318** positioned within the vicinity of the thermal elements **23** can be configured to measure the temperature of the adhesive at different locations throughout the applicator **10** and transmit a heat signal to the controller **7** that is representative of the temperature of the adhesive. This measuring step can be performed at any time with respect to previously described steps **402**-**466**, such that it can be performed simultaneously with the steps where the controller **7** determines adjustments to the operating speeds of the pump assemblies **20***a*-**20***f* and the recirculation pump assembly **20***g*. After step **470** is performed, in step **474** the controller **7** can determine a property of the adhesive based on the temperature of the adhesive as detected by the heat sensors **318**. For example, this property can be a viscosity of the adhesive, and can be determined by the controller **7** based upon the temperature measured by the heat sensors **318** and compared to known material properties of the adhesive, though other properties are contemplated.

The heat sensed in step **470** by the heat sensor **318** can also be utilized by the controller **7** in determining an adjustment to the operating speed of the pump assemblies **20***a***-20***f* and/or the recirculation pump assembly **20***g*.

In step **478**, the position sensors **314***a***-314***f* are configured to measure an instantaneous position of a valve stem **260** of a corresponding one of the dispensing modules **16***a***-16***f* and send a signal to the controller **7** through the signal connection **8** that is representative of the instantaneous position. Like step **470**, this measuring step can be performed at any time with respect to previously described steps **402-466**, such that it can be performed simultaneously with the steps where the controller **7** determines adjustments to the operating speeds of the pump assemblies **20***a***-20***f* and the recirculation pump assembly **20***g*. Using the instantaneous positions of the valve stems **260** measured in step **478**, in step **482** the controller **7** can determine whether a defect exists in the dispensing system. Such a defect can include a clog within the material flow path, component failure, etc., and can affect the positioning of the valve stems **260** by causing the time required for the valve stems **260** to complete a full stroke length to increase. In addition to the instantaneous position measured by the position sensors **314***a***-314***f*, the measurements measured by the first and second sensors **302**, **304**, pressure sensors **310***a***-310***f*, pump sensors **311***a***-311***f*, recirculation pump sensor **310***g*, and heat sensors **318** can also be utilized in making this determination. Further, the instantaneous position measured by the position sensors **314***a***-314***f* can also be utilized in the determination of the adjustment to the operating speed of the pump assemblies **20***a***-20***f* and/or the recirculation pump assembly **20***g*.

As the flow of adhesive to each dispensing module **16***a***-16***f* is individually controlled by a respective pump assembly **20***a***-20***f*, aspects of the flow of adhesive to an individual dispensing module **16***a***-16***f* can be adjusted without altering the operation of other portions of the dispensing system **1**. The addition of the first and second sensors **302**, **304**, the pressure sensors **310***a***-310***f*, the position sensors **314***a***-314***f*, and the heat sensors **318** allow the flow of adhesive within the applicator **10** to be monitored with a higher level of precision and a higher resolution, while simultaneously allowing changes or issues within the applicator **10** to be reacted to quicker. The ability of the controller **7** to receive and utilize the entirety of the measurements taken by the above-described sensors allows the controller **7** to react faster than prior systems when a change within the applicator **10** must be made and adjust operation of any combination of the pump assemblies **20***a***-20***f* and/or recirculation pump assembly **20***g*, which can save on wasted adhesive and result in less unsalable finished product.

Another embodiment of the present disclosure is a hybrid applicator for dispensing the adhesive. FIG. **19** illustrates an applicator **510**. The hybrid applicator **510** is configured for both metered output and pressure fed output. The applicator **510** is similar to the applicator **10** described above. For instance, the hybrid applicator **510** includes dispensing module(s) **516** and a unitary or segmented manifold **512**.

The hybrid applicator **510** includes at least one pump assembly **420** (or pump assembly **120**) and at least one pressure feed block **520**, each of which is coupled to the manifold **512**. Regarding this embodiment, reference number **420** can be used interchangeably with the reference number **520***a***-520***c* unless noted otherwise. In accordance with the embodiment illustrated in FIG. **16**, the applicator **10** includes three pump assemblies **520***a*, **520***b* and **520***c*, as well as four pressure feed blocks **522***a*, **522***b*, **522***c* and **522***d*. However, the applicator **510** can include any number of pump assemblies **420** and pressure feed blocks **520**. Any of the pump assemblies **520***a***-520***c* can be configured to operate as the recirculation pump assembly, as described in relation to pump assembly **20***g* above.

Continuing with FIG. **19**, the pump assembly **420** is substantially the same as pump assembly **20** (or pump assembly **120**), as described above. The pump assembly **420** receives adhesive from flow channels in the manifold **512**, which are ported to the input **519***c*. Pressure feed blocks **522***a* and **522***c* include inlets and outlets that receive adhesive from the manifold supplied through the input **519***c*. The pressure feed blocks **522***b* and **522***d* are supplied adhesive through inputs **519***a* and **519***b*, which receive adhesive from an adhesive supply (not shown). A pump (not shown) near the adhesive supply may be used to feed the adhesive through hoses to inputs **519***a* and **519***b*, which are coupled to the pressure feed blocks **522***b* and **522***d*, respectively. Heat from the manifold **512** then is transferred to the pressure feed blocks **522***a***-522***d*, thereby heating the adhesive within the pressure feed block **520**. As shown, the hybrid applicator **510** has multiple input fittings **519***a***-519***c*, some which are associated with a pressure feed block(s), that can be used to supply different types of adhesive to the applicator **510**.

Combining a pump assembly **420** with a pressure feed block **520** increases process flexibility of the applicator **510**. For example, the pump assembly **420** permits precise metering of adhesive streams from the dispensing module **516**, while other adhesive streams are associated with the less precise pressure feed blocks **520**. It should be appreciated that the hybrid applicator **510** can be metered, pressure-fed, and multi-zone pressure-fed, all within a single manifold as needed.

While the invention is described herein using a limited number of embodiments, these specific embodiments are not intended to limit the scope of the invention as otherwise described and claimed herein. The precise arrangement of various elements and order of the steps of articles and methods described herein are not to be considered limiting. For instance, although the steps of the methods are described with reference to sequential series of reference signs and progression of the blocks in the figures, the method can be implemented in any particular order as desired.

What is claimed is:

1. A dispensing system for dispensing adhesive, the dispensing system comprising:
- an applicator comprising:
  - a manifold;
  - a plurality of dispensing modules coupled to said manifold; and
  - a plurality of pump assemblies, wherein each of the plurality of pump assemblies is configured to pump the adhesive to a respective one of the plurality of dispensing modules at a respective operating speed; and
- a controller in signal communication with the applicator, wherein the controller is configured to a) measure current draw from each of the plurality of pump assemblies, b) determine an adjustment to the operating speed of each of the plurality of pump assemblies individually based on their respective current draws, and c) direct each of the plurality of pump assemblies to individually adjust their operating speed.

2. The dispensing system of claim **1**, wherein the applicator further comprises:
- a supply channel configured to provide the adhesive to the plurality of pump assemblies;

a recirculation channel configured to receive the adhesive from the plurality of pump assemblies and direct the adhesive to the supply channel; and

a recirculation pump assembly configured to control flow of the adhesive through the recirculation channel.

3. The dispensing system of claim **2**, wherein the applicator further comprises:

a plurality of pressure sensors each configured to measure a pressure of the adhesive pumped from a respective one of the plurality of pumps to a corresponding one of the plurality of dispensing modules, and send a signal to the controller that is representative of the pressure.

4. The dispensing system of claim **3**, wherein the applicator further comprises:

a recirculation pressure sensor configured to measure a pressure of the adhesive flowing through the recirculation channel and send a signal to the controller that is representative of the pressure,

wherein the controller is configured to determine an adjustment to an operating speed of the recirculation pump assembly so as to equalize the pressure measured by the recirculation pressure sensor and the pressures measured by the pressure sensors.

5. The dispensing system of claim **2**, wherein the controller is in signal communication with the recirculation pump assembly, the controller being further configured to measure current draw from the recirculation pump assembly and determine an adjustment to the operating speed of the recirculation pump assembly based on the current draw from the recirculation pump assembly.

6. The dispensing system of claim **5**, wherein the applicator further comprises a plurality of pump sensors and a recirculation pump sensor, wherein the plurality of pump sensors and the recirculation pump sensor are configured to measure motor torque and operating speed of the plurality of pump assemblies and recirculation pump assembly, respectively, and a pump pressure of the adhesive exiting the plurality of pump assemblies and the recirculation pump assembly, respectively.

7. The dispensing system of claim **1**, wherein each of the plurality of dispensing modules includes a valve stem that is configured to control flow of adhesive from the plurality of dispensing modules, the applicator further comprising:

a plurality of position sensors, wherein each of the plurality of position sensors is configured to measure an instantaneous position of a respective one of the valve stems and send a position signal to the controller that is representative of the instantaneous position of the respective one of the valve stems,

wherein the controller is configured to determine whether a defect exists in the dispensing system based on the instantaneous positions.

8. The dispensing system of claim **1**, wherein the applicator further comprises:

a plurality of thermal elements for heating the adhesive; and

a plurality of heat sensors, wherein each of the plurality of heat sensors is positioned adjacent a respective one of the plurality of thermal elements and in fluid communication with the adhesive, such that the plurality of thermal elements are configured to detect a temperature of the adhesive and transmit a heat signal to the controller that is representative of the temperature of the adhesive,

wherein the controller is configured to determine a property of the adhesive based on the temperature of the adhesive.

9. The dispensing system of claim **1**, wherein the controller is configured to direct each of the plurality of pump assemblies to individually adjust their operating speeds when their respective current draws are outside a predetermined range.

10. The dispensing system of claim **9**, wherein the controller is configured to direct each of the plurality of pump assemblies to individually maintain their operating speeds when their respective current draws are within the predetermined range.

11. The dispensing system of claim **9**, wherein the controller includes a human-machine interface (HMI) device configured to produce an alert when the current draw of one of the plurality of pump assemblies is outside the predetermined range.

12. The dispensing system of claim **11**, wherein the HMI device is configured to receive a user input to manually select the predetermined range.

13. The dispensing system of claim **1**, further comprising:

a melter configured to melt the adhesive and provide the adhesive to the applicator.

14. A method of controlling dispensing of adhesive from an applicator, comprising:

pumping adhesive from a plurality of pump assemblies to a plurality of dispensing modules;

measuring current draw from each of the plurality of pump assemblies;

determining an adjustment to an operating speed of each of the plurality of pump assemblies individually based on their respective current draws; and

adjusting the operating speed of each of the plurality of pump assemblies individually.

15. The method of claim **14**, further comprising:

directing the adhesive through a supply channel to the plurality of pump assemblies; and

pumping the adhesive from the plurality of dispensing modules through a recirculation channel and to the supply channel via a recirculation pump assembly.

16. The method of claim **15**, further comprising:

measuring a recirculation pressure of the adhesive flowing through the recirculation channel;

measuring a dispensing pressure of the adhesive flowing from each of the plurality of pump assemblies to the respective one of the plurality of dispensing modules; and

adjusting an operating speed of the recirculation pump assembly so as to equalize the recirculation pressure with the dispensing pressure.

17. The method of claim **15**, further comprising:

determining current draw from the recirculation pump assembly;

determining an adjustment to an operating speed of the recirculation pump assembly based on the current draw; and

adjusting the operating speed of the recirculation pump assembly.

18. The method of claim **17**, further comprising:

measuring motor torque, operating speed, and pump pressure of the recirculation pump assembly,

wherein determining the adjustment to the operating speed of the recirculation pump assembly includes determining the adjustment to the operating speed of the recirculation pump assembly based on the motor torque, operating speed, and pump pressure.

19. The method of claim **14**, further comprising:

measuring motor torque, operating speed, and pump pressure of each of the plurality of pump assemblies, wherein determining the adjustment to the operating speed of each of the plurality of pump assemblies includes determining the adjustment to the operating speed of each of the plurality of pump assemblies individually based on the motor torque, operating speed, and pump pressure of each of the plurality of pump assemblies.

20. The method of claim **14**, further comprising:

measuring an instantaneous position of a valve stem of each of the plurality of dispensing modules; and

determining whether a defect exists in the applicator based on the instantaneous positions.

21. The method of claim **14**, further comprising:

measuring a temperature of the adhesive; and

determining a property of the adhesive based on the temperature of the adhesive.

22. The method of claim **14**, wherein adjusting the operating speed of each of the plurality of pump assemblies individually includes adjusting the operating speed of each of the plurality of pump assemblies when their respective current draws are outside a predetermined range.

23. The method of claim **22**, wherein adjusting the operating speed of each of the plurality of pump assemblies individually includes maintaining the operating speed of each of the plurality of pump assemblies when their respective current draws are within the predetermined range.

24. The method of claim **22**, further comprising:

producing an alert when the current draw of one of the plurality of pump assemblies is outside the predetermined range.

25. The method of claim **22**, further comprising:

receiving a user input to manually select the predetermined range.

* * * * *